NEW

THE MAGAZINE THAT FEEDS MINDS

HOW IT WORKS

SCIENCE | ENVIRONMENT | TECHNOLOGY | TRANSPORT | HISTORY | SPACE

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UPGRADE YOUR EYES!

SHARK ATTACK

How one of the planet's oldest killers hunts its prey

FIREWORKS

The simple science behind breathtaking displays revealed

WHY WE GET DRUNK

The effects of alcohol on the body

EXTREME WEATHER

Tornadoes, tsunamis and hurricanes

iPHONE 3GS

Inside the world's greatest gadget

831 FACTS AND ANSWERS INSIDE

TYPHOON VS F-22 RAPTOR

THE SCIENCE AND TECHNOLOGY BEHIND THE WORLD'S MOST ADVANCED FIGHTER JETS

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WELCOME

The magazine that feeds minds! ISSUE ONE

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Have YOU got a question you want answered by the How It Works website? Get in touch by..

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Bournemouth, Dorset BH2 6EZ

"FEED YOUR MIND!"

The sections explained

The huge amount of info in each issue of How It Works is organised into these sections

ENVIRONMENT
The natural world explained

SCIENCE
Explaining the applications of science in the contemporary world

HISTORY
Questions answered on how things worked in the past

TECHNOLOGY
The wonders of modern gadgetry and engineering explained

TRANSPORT
Be it road, rail, air or sea you'll find out about it here

SPACE
From exploration to the solar system to deep space

Meet the experts

How It Works is put together by a crack team of knowledge-rich experts, here are some of them who we feel deserve a special mention this issue

Phil Raby
Eurofighter vs F-22

Phil's area of speciality is cars, especially Porsches, although he appreciates all forms of engineering and loves to take things to bits. He's a self-confessed gadget junkie and is never far from his iPhone.

Dave Roos
Extreme weather

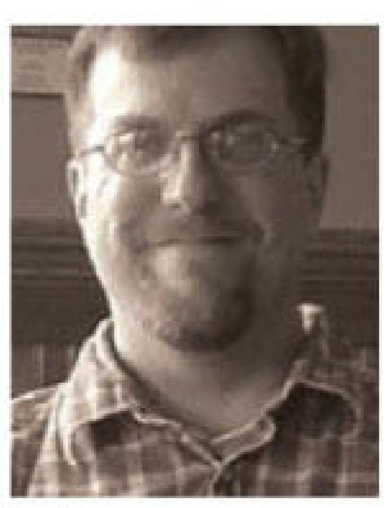
Dave Roos is a freelance writer and part-time farmer who recently returned to the United States after six years in Mexico. He has written for *The New York Times*, *Newsweek* and other bigshot publications.

Tom Harris
Return of the LHC

Tom Harris is a writer from Durham, North Carolina. He has contributed to 16 general knowledge books and was one of the original writers at HowStuffWorks.com, where he led the award-winning content team.

Shanna Freeman
Medieval castles

Shanna Freeman holds a BA in English and lives near Atlanta, Georgia. She enjoys writing about a variety of topics, including food, science, health, history, technology and pop culture.



John Brandon
Inside the Sun

John Brandon is a freelance writer with articles published in many major computing, science, travel, and music magazines. Since starting his writing career in 2001, he has had over 2,500 articles published.

With thanks to

How It Works would like to thank the following companies and organisations for their help in creating this issue

BUGATTI · ROYAL NAVY · NASA · DK · REUTERS · HISTORY · GARMIN · BAE SYSTEMS · sciencemuseum

Welcome to How It Works, the new magazine that explains everything you never knew you wanted to know about the world we live in. Loaded with fully illustrated guides and expert knowledge, and with sections dedicated to science, technology, transportation, space, history and the environment, no subject is too big or small for How It Works to explain.

So why did we launch a new science and technology magazine? Quite simply, because there's a huge audience that want accessible, entertaining and absorbing info-tainment packed with fact and opinion to fuel their imaginations. You only need to look at the success of TV programmes like *Brainiac: Science Abuse*, *James May's Big Ideas* and *Richard Hammond's Engineering Connections* to see that science and technology is firmly part of mainstream entertainment.

Entertainment and information is what How It Works delivers in spades, we aim to answer the most fascinating questions you can think of. How do sharks hunt? What's a black hole? What's inside a nuclear submarine? How was the London Underground built? How do iPods work? These are just a few of the questions we'll be answering in coming issues. Our launch issue tackles such awe-inspiring subjects as the Eurofighter, the causes of extreme weather such as tsunamis and hurricanes, the Bugatti Veyron, vision and sight, nuclear subs and the Large Hadron Collider. All written by our experts and all enjoyable to anyone with a hunger for knowledge. So, read, absorb, enjoy and feed your mind. If you enjoy reading it half as much as I enjoyed editing it you'll have got your money's worth… and then some!

Dave Harfield
Editor-in-Chief

Editor's pick

This issue is packed out with great features but my favourite article this month has to be the look inside the HMS Astute. If you've ever wanted to find out what's beneath the hull of the Royal Navy's latest and most deadly nuclear sub, turn to page 48.

HOW IT WORKS

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The magazine that feeds minds!

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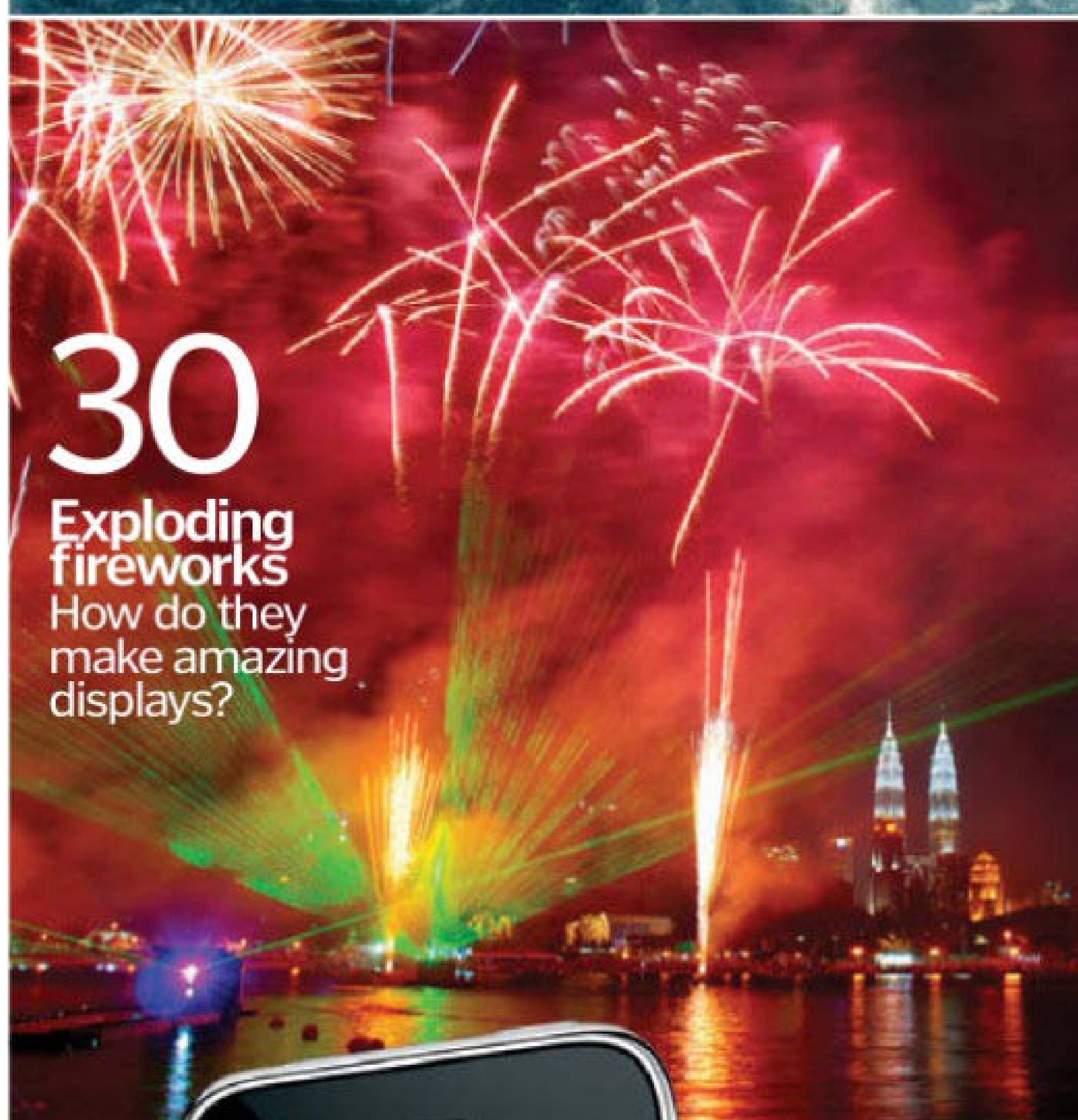

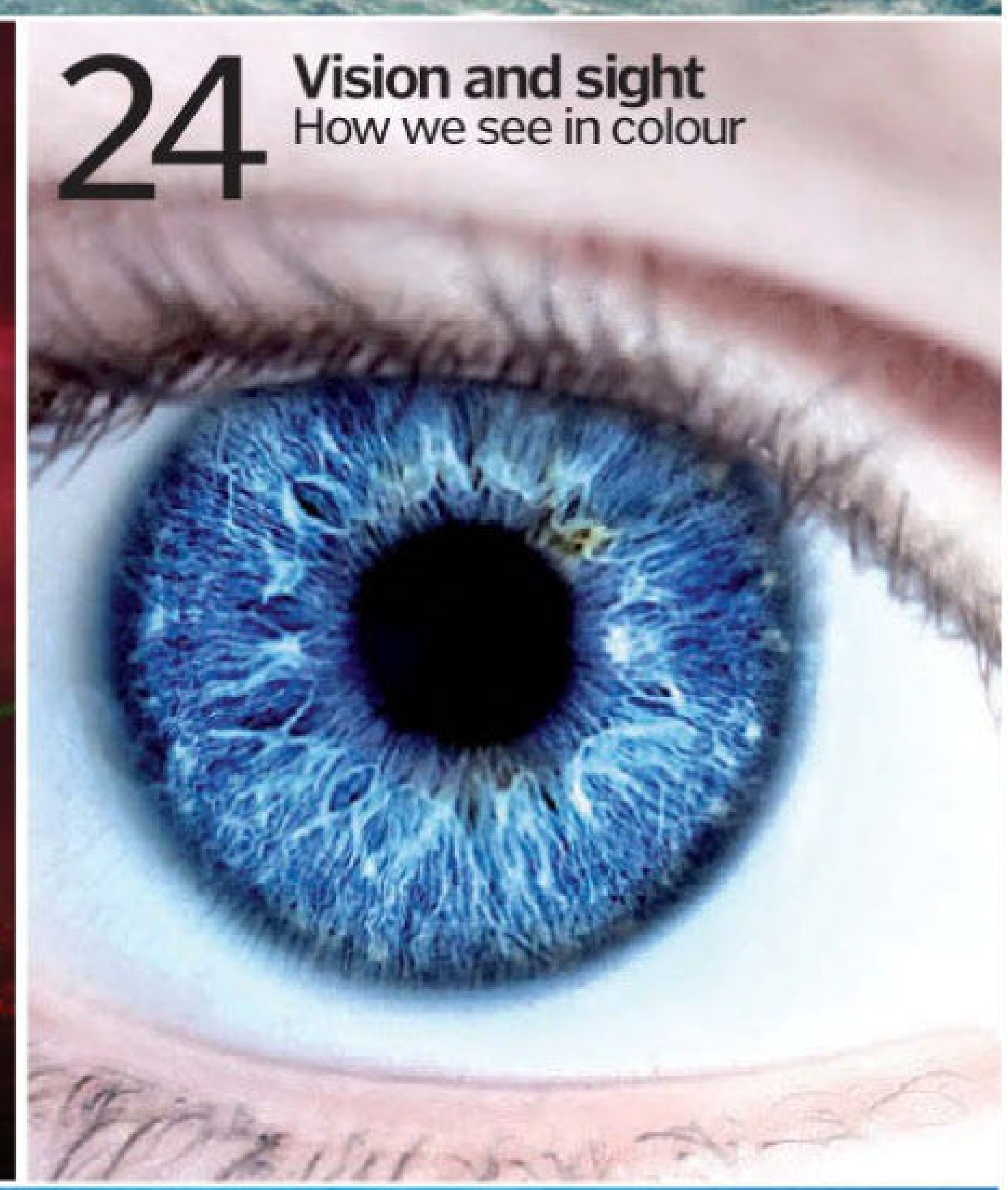

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Rob Skitmore
Assistant Curator of Technology
Rob tackles all questions related to technology

Rik Sargent
Science Museum Explainer
Rik-of-all-trades answers a wide variety of questions

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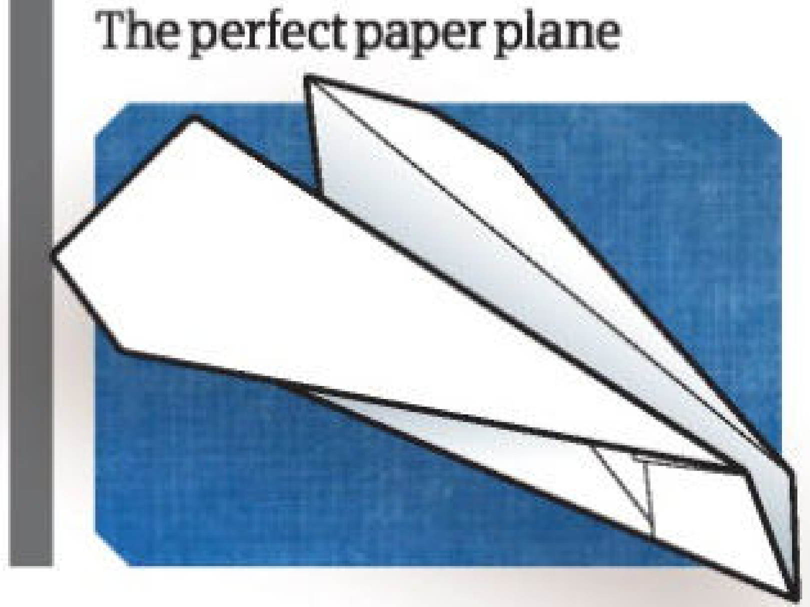
For connoisseurs of kit and savants of stuff



Sydney gets red mist

This was the scene near the Sydney Opera House in September as a huge Outback dust storm swept across the east of the country, clogging the air with 15,500 micrograms of particles per cubic metre

Sushi skutter

Debuting at the food machinery and technology exhibition in Tokyo, this skutter-like robot's hands are soft and have very few metal parts in order to handle delicate objects without crushing them.

Image © Reuters

DIY submarine

Amateur inventor Tao Xiangli is shown here proudly showing off his home-made submarine in Beijing this month. Built from oil drums and scrap parts, the sub is fully functional and sports a periscope, depth control tanks, electric motors and two propellers.

Image © Reuters

GLOBAL EYE

The most sensational news and pictures from around the world

Showcasing the incredible world we live in...

Tackling wild fires

Firefighters in LA drop a load of water on a raging wild fire. The water is dyed red to help them better target the drop.

Image © Reuters

Image © Getty

Milking the snake

A volunteer brings a western diamondback rattlesnake in for milking at the Rattlesnake Roundup 2009, Sweetwater, Texas. Approximately 240,000 pounds of rattlesnakes will be collected, milked for venom and the meat served to support charity.

How do you make a baby panda?

In the case of female panda Lin Hui from Chiang Mai zoo, Bangkok, it took two artificial inseminations to produce this cute little fella, even playing videos of other pandas mating failed to get her in the mood. With fewer than 3,000 pandas believed left in the wild, every new cub born in captivity is essential for the survival of the species.

Image © Reuters

Next stop: International Space Station

The Soyuz TMA-16 launches from the Baikonur Cosmodrome in Kazakhstan on Wednesday 30 September 2009, carrying Expedition 21 flight engineer Jeffrey N Williams, flight engineer Maxim Suraev and spaceflight participant Guy Laliberté to the International Space Station.

HOW IT WORKS
GLOBAL EYE NEWS
A fresh look at the world

NASA assures us that asteroid will miss

End of the world is cancelled

Stop hoarding food and building that fallout shelter as NASA has recently assured us that the Apophis asteroid will not be hitting the Earth in 2029.

Previously it was thought Apophis, which is around the size of two and a half football pitches, would hit Earth sometime in that year with some sources even pinpointing the day of impact as Friday 13 April, very fitting indeed. Fans of the apocalypse will be disappointed to hear that NASA refined the path of the asteroid in October and found that it will in fact miss Earth completely, although it will set a record close approach by skimming just 18,300 miles above Earth's surface, a near miss in astronomical terms.

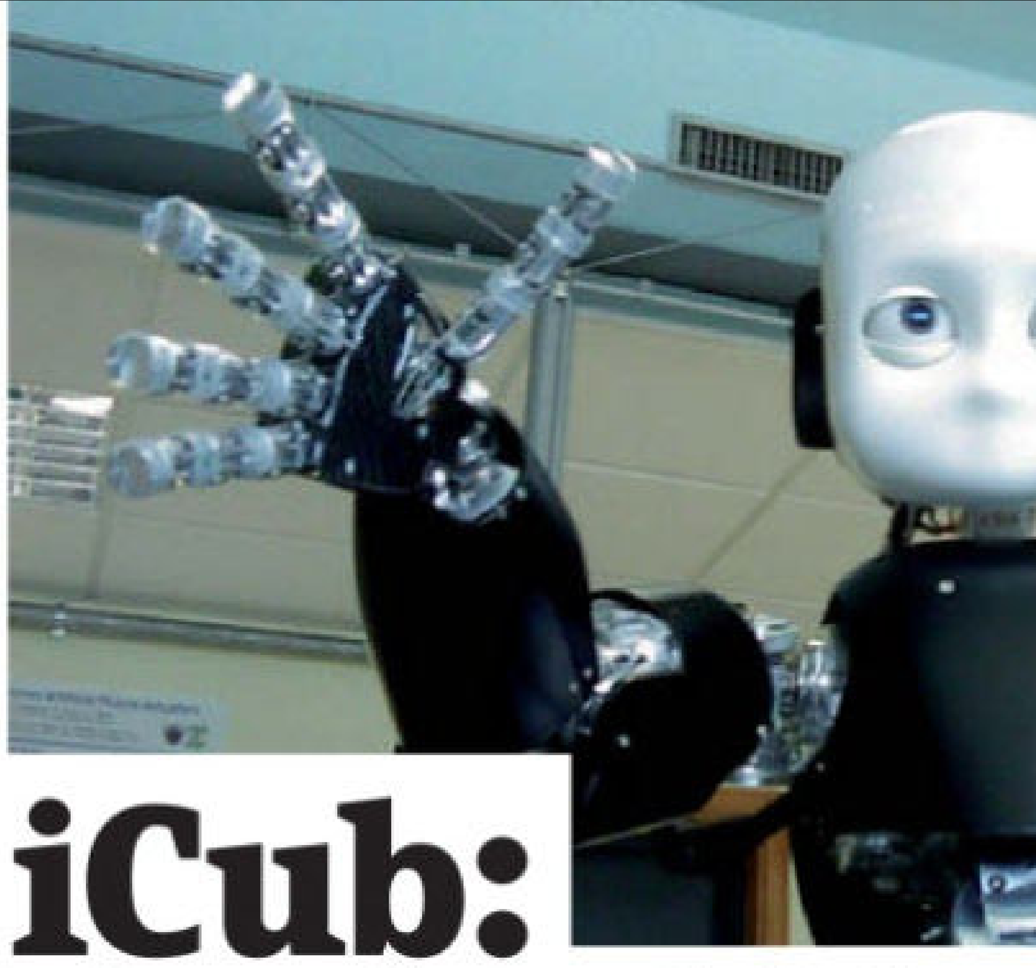
In fact this is within the distance of Earth's geosynchronous satellites, satellites whose orbital track on the Earth repeats regularly over points on the planet over time. However, the path that Apophsis will take, inclined at 40 degrees to the Earth's equator and inside the position of the satellites at closest approach, makes a collision unlikely even in this heavily populated region of space.

Another close encounter with this particular asteroid is predicted for 2068 with the chance impact listed at three-in-a-million, although this probability is expected to decrease even further as more information about Apophis and its orbit is acquired over time.

The science of predicting asteroids is based on a physical model of the solar system which includes the gravitational influence of the Sun, moon, planets and the three largest asteroids, Ceres, Pallas, and Vesta.

Speaking in a NASA press release Don Yeoman, manager of the Near-Earth Object Program Office at JPL, said "The refined orbital determination further reinforces that Apophis is an asteroid we can look to as an opportunity for exciting science and not something that should be feared."

If you want to find more information on asteroids and near-Earth objects, visit **http://www.jpl.nasa.gov/asteroidwatch** or follow AsteroidWatch on Twitter.



iCub: The robot child

This creepy looking robot kid might learn to speak quicker than your own

This is iCub, a small humanoid robot about the same size as a three-and-a-half-year-old child that might enable a new insight into human cognitive behaviour.

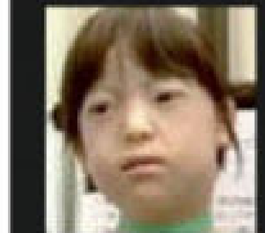
Standing one metre high, the iCub has articulated arms, legs and trunk and eyes that can follow moving objects. The cyber-toddler can also recognise and grasp objects, walk and crawl just like its human counterparts and more impressively, scientists think it can learn via these everyday interactions.

Experts in cognitive robotics research from Plymouth University are working with language boffins to teach the iCub basic phrases for what's known as the ITALK (Integration and Transfer of Action and Language Knowledge in robots) project. Having won a £4.7 million grant for the project, ITALK started in March this year with professor of artificial intelligence, Angelo Cangelosi, hoping to redefine robots as we know them, "The outcome of the research will define the scientific and technological requirements

Top 3 creepy robots on YouTube

If you find that iCub's blank visage and big, unblinking eyes freak you out a little, take a look at these silicon horrors online now.

Japanese child robot
http://tinyurl.com/d5m4zl
Makes a disturbing eeh! eeh! noise that could be the last thing you ever hear.



Freaky robot girl
http://tinyurl.com/yhvmdn5
This little robot girl has been haunting our dreams for three weeks now. Horrid.

The real fembot
http://tinyurl.com/34jevm
We thought of a number of uses for this android, all of them morally repugnant.

This day in history

29 October: Major events that occurred on the same day this magazine was launched

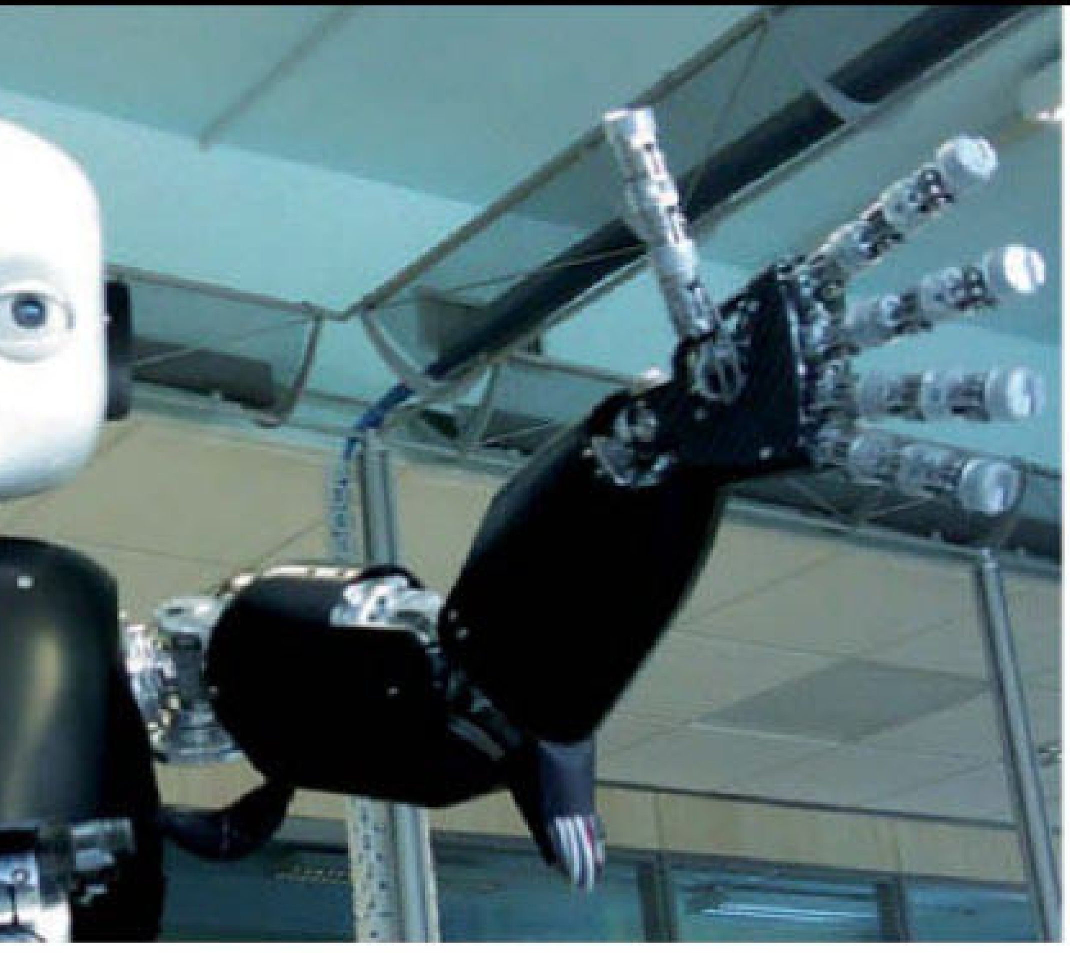
1618 Sir Walter Raleigh, English adventurer, writer, and courtier, is beheaded for allegedly conspiring against James I of England

1787 Mozart's opera *Don Giovanni* receives its first performance in Prague

1956 Suez Crisis begins: Israeli forces invade the Sinai Peninsula and push Egyptian forces back toward the Suez Canal

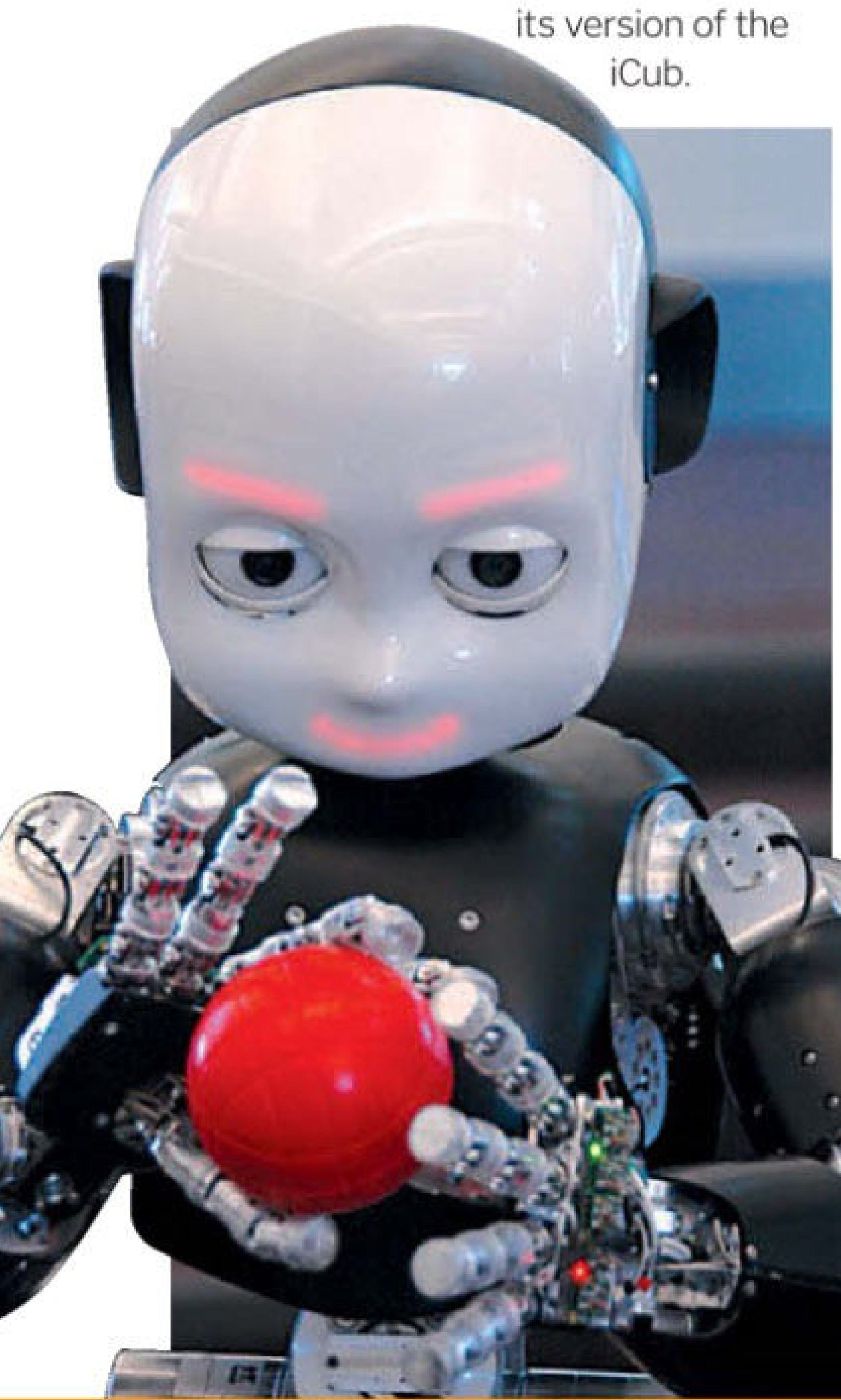
1960 Cassius Clay (who will later be known as Muhammad Ali) wins his first professional fight in Louisville, Kentucky

1967 London criminal Jack McVitie is murdered by the Kray twins, leading to their downfall and eventual imprisonment



for the design of humanoid robots able to develop complex behavioural, thinking and communication skills through individual and social learning."

The learning activities taught to the iCub are remarkably similar to those that a parent would engage in with a child, or a child would perform at nursery school: the iCub will stack blocks to form basic constructions and insert shapes into holes, while being taught names for objects and stringing basic sentences together. The significance of this project is in bringing us closer to creating an android: true artificial intelligence in a robot that can talk, behave like a human and learn through independent and social learning. There are six iCubs currently in projects in various laboratories over Europe, with the French research facility based in Lyon also boasting advances in interaction and basic game-playing with its version of the iCub.



Exclusive! First look at the Mac Tablet we received from an anonymous source this week. We certainly didn't mock it up in Photoshop. Oh no...

Rumours of an Apple 'iTablet' continue apace

iPod manufacturer prepares to redefine print media with touch-screen device

Rumours of a touch-screen tablet computer from Apple continue to build up steam following a number of leaks and analyst predictions.

While details surrounding the device are sketchy at best, sources claim that the company, famed for its iPhone, has been working on a touch-controlled computer concept since 2003. Industry insiders and media outlets speculate that while the technology currently exists to build such a device, Apple's enigmatic CEO Steve Jobs has played a hand in shelving the product on a number of occasions until a 'killer feature' had been established to set it apart from similar devices.

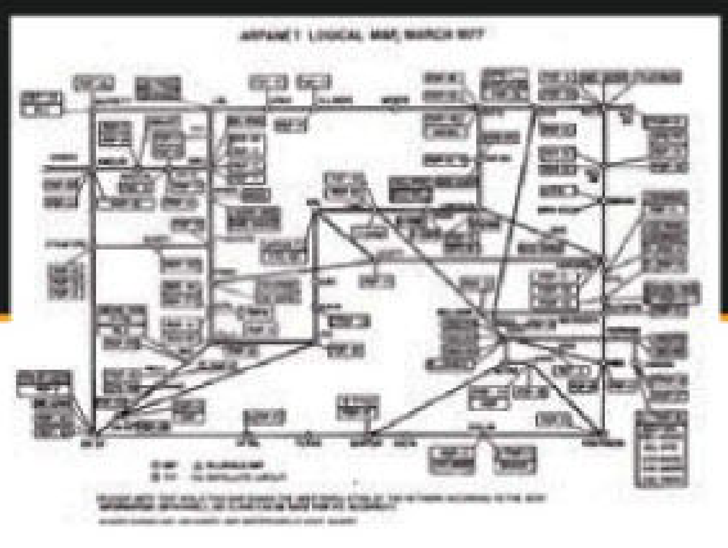
Fans of Apple's MacBook laptop and iPod portable media player have been clamouring after a computer that would marry the two disciplines, however the logistics of such a device may not be feasible in terms of cost and practicality. Many sources suggest that, in order to power the screen and processor, an existing laptop battery may last too short a time to be worthwhile to the consumer and that the components would be too costly to make the device affordable.

With Apple already riding high on the success of its iPhone and iPod touch and with a strong base of application developers providing software for its App Store, it seems the next logical step would be to bring its multi-touch interface and operating system to a larger platform, but without a niche in the market this could take time.

Talk in Silicon Valley points towards a possible partnership between Apple and the news press, including *The New York Times*, to 'redefine' print media by offering it on a touch screen complete with an internet connection for live updates. Amazon's Kindle eBook reader is a likely target should Apple decide to take this route to market, intending to revolutionise the news in the same way it changed the marketplace for music.

No concrete details have been uncovered to suggest that an Apple tablet will see the light of day, however current rumours are slating a release in the first quarter of 2010.

1969 The first-ever computer-to-computer link is established on ARPANET, the precursor to the internet



1986 British Prime Minister Margaret Thatcher opens the fianl stretch of the M25 motorway

1991 The American Galileo spacecraft makes its closest approach to 951 Gaspra, becoming the first probe to visit an asteroid

1998 Space Shuttle Discovery blasts off on STS-95 with 77-year-old John Glenn on board, making him the oldest person to go into space

GLOBAL EYE NEWS

A fresh look at the world

Obama awarded Nobel peace prize

Decision to make Obama the third president in history to receive the award divides world leaders

US President Obama's Nobel prize for peace award earlier this month has stirred controversy among leading world figures.

Obama received the prestigious award for his immediate efforts to promote world peace following his election, including a call to world leaders to promote peace and co-operation, pledging to reduce America's nuclear stockpile, his attempts to improve Arab-American relations and a move towards a greener America.

Many people have voiced their concern however, including former Polish president Lech Walesa, who spoke to The Associated Press, suggesting that Obama has received the prize too soon. "Too early. He has no contribution so far. He is only beginning to act," Walesa stated.

The Norwegian Nobel Committee naturally voiced their justification, saying that, "It could be too late to respond three years from now," and it wasn't the only figurehead to support the decision. "It is an award that speaks to the promise of President Obama's message of hope," said Archbishop Desmond Tutu, who won the award in 1984.

Obama has donated the $1.4 million prize to various charities.

The unmanned LCROSS (Lunar Crater Observation and Sensing Satellite) mission cost a relatively cheap $79 million

NASA's deliberate moon crash

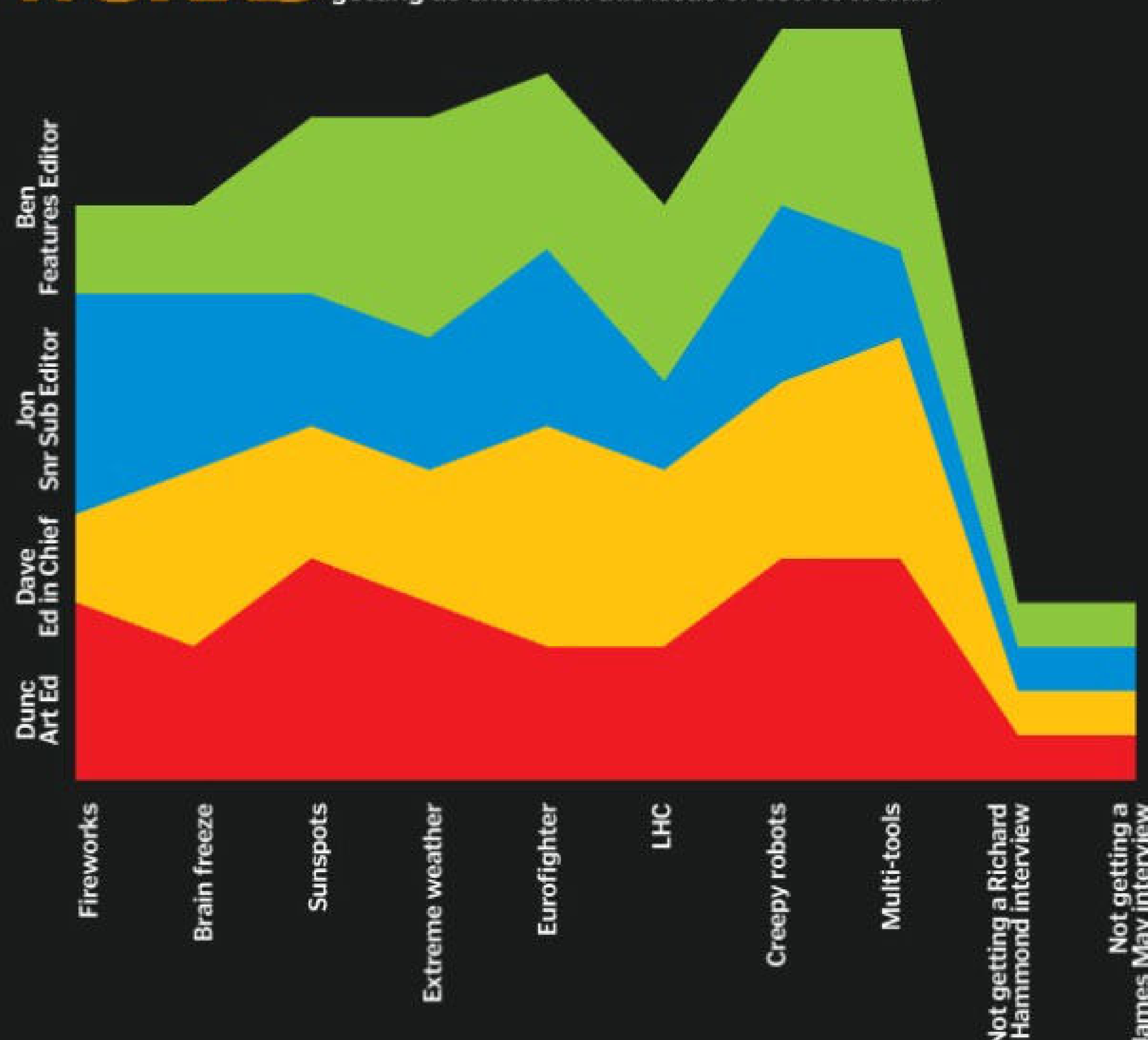
NASA's search for a substance more valuable than gold culminates in moon crash

In the search for lunar ice, a resource worth more than gold to NASA, the space agency has crashed two of its craft into the moon. The crash and deep impact will kick up a dust cloud from which ground control used light wavelengths to glean vital data about the composition of Moon's surface. Though a disappointed public didn't receive the spectacle it expected, NASA was pleased with the results. "It wasn't a dud," said physicist Michio Kaku to The Associated Press, "We got a gold mine of data."

It's long been suspected that vast amounts of ice is mixed in with lunar soil, known as regolith, ever since the Clementine project in 1994 and subsequent Lunar Prospector sent out in 1998 revealed the possibility of 6.6 billion tons of ice at the lunar poles. Shipping water to the moon is prohibitively expensive (up to $20,000 a kilo), so this vast amount of ice represents a real possibility for lunar colonisation in the future.

HOW IT WORKS EXCITE-O-METER!

Every issue we offer this visual guide to what's been getting us excited in this issue of **How It Works**



It turns out that Duncan Crook, Art Editor, was the most excited member of staff this issue with a total excitement rating of some 68 per cent. Jon White, Senior Sub Editor, really should cheer up, scoring a feeble 60 per cent.

BigDog: the faithful army robot

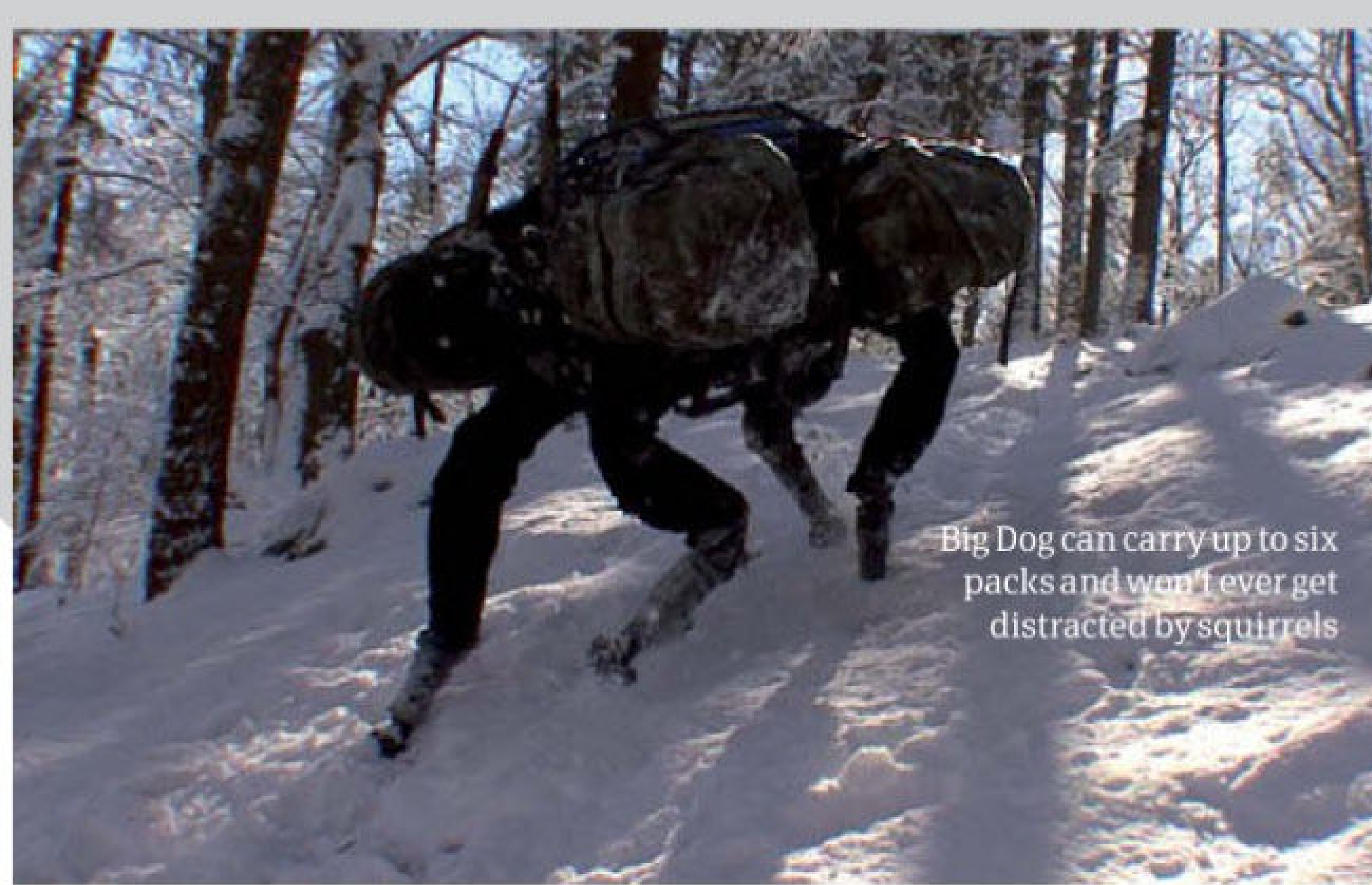
Boston Dynamic's incredible quadruped robot will help soldiers haul gear across rough terrain

This 240-pound, three-foot-long headless hunk of metal may be a lousy cuddler, but it can walk and hop like a real dog, even on ice and rubble.

It also carries 350 pounds of gear, trots at 4mph, and climbs up 35-degree slopes. Hydraulic actuators, like you would find in a backhoe, act as 'muscles', moving the robot's legs. A noisy 15-horsepower two-stroke go-kart engine powers a pump that provides pressurised oil to the hydraulic system.

BigDog's brain is an onboard Pentium CPU computer that analyses data from an electronic gyroscope, force detectors in the feet, stereo cameras, and other sensors to gauge the robot's exact position. The computer continually calculates how to reposition each one of the legs to keep BigDog upright and moving in the correct direction.

In a popular YouTube video, BigDog even keeps its balance after a man delivers a powerful kick (guess he hasn't seen *Terminator*).



Big Dog can carry up to six packs and won't ever get distracted by squirrels


htc
MY WORLD,
MY RULES
Living life in the fast lane, I need a phone that changes as quickly as my day. A simple slide across the screen from 'Work' to 'Play' and my phone is less office boardroom and more broadwalk in Manhattan.
In the story of my life, I'm the star. My phone is the HTC Hero.
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This month in **Environment**

The natural world is full of wonder and so we're spoilt for choice when it comes to investigating amazing animals, locations or phenomena. If you've ever wondered how tsunamis are formed, how hurricanes happen, or what makes blizzards goes berserk, our main feature focuses on the causes of extreme weather.

18 Snake bites

21 Shark attacks

22 Volcanoes

ENVIRONMENT

Extreme

The making of a tsunami

How a deep-sea rumble forges a killer wave

On 26 December 2004, a 9.0 magnitude earthquake off the coast of Sumatra, Indonesia triggered a series of tsunamis – giant seismic sea waves – that claimed 300,000 lives around the Indian Ocean basin. It was deadliest natural disaster in recorded history.

Tsunamis are not 'tidal' waves. They are created when a violent geological event – like a submarine earthquake, landslide or underwater volcanic eruption – displaces a huge amount of water.

The Indian Ocean earthquake occurred along a subduction zone, a place where one tectonic plate wedges under another. During the record-setting quake – which released more energy than 23,000 Hiroshima-era atomic bombs – a section of sea floor 1,000 kilometres long was pushed ten metres horizontally and several meters vertically.

The violent displacement generated a massive deep-ocean wave only a few meters high, but hundreds of kilometres long. The almost imperceptible swell travelled across the open water as fast as a jet aeroplane. As the deep-ocean seismic wave neared the shore, it was slowed down by the quickly rising sea floor. But as the wave compressed horizontally, it rose vertically, reaching heights of 30 metres in some cases.

DID YOU KNOW?

The most tornadoes...

There are more tornadoes in America than any other country. Supercell formation is fuelled by warm, moist air from the Gulf of Mexico meeting cool, dry air blowing over the Rockies.

e weather

Marvel at the raw power of nature at its nastiest

A gust of air rattles the windows. The sky darkens ominously as coal-black clouds creep across the horizon. Thunder rumbles thickly in the distance accompanied by the first flickers of lightning, like paparazzi.

Suddenly, the rain comes down in sheets, blown sideways by howling winds. With a crackling explosion, a tree across the street is torn in half by a stroke of lightning. But as suddenly as it started, the rain stops. The clouds remain low and terribly dark, almost green. You look out the back window in search of a reprieve. Instead, you see the twister.

Mother Nature deserves respect. Before you complain about the light drizzle that spoiled your picnic, thank your lucky stars you've never experienced a true weather disaster: a six-story tsunami wave, 150kph hurricane winds, or tornadoes that can toss an 18-wheeler like a Matchbox car.

We'll help you make sense of the Weather Channel chatter and learn what causes the world's most extreme weather phenomena.

Tornadoes explained

Why twisters descend from the sky and drill a path of destruction

Tornadoes are born in beefed-up storm clouds called supercells. While normal storm clouds form and dissipate in 30 minutes, supercells can last for hours and spread severe weather across hundreds of kilometres. But the most unique characteristic of a supercell is its powerful counter-clockwise rotation.

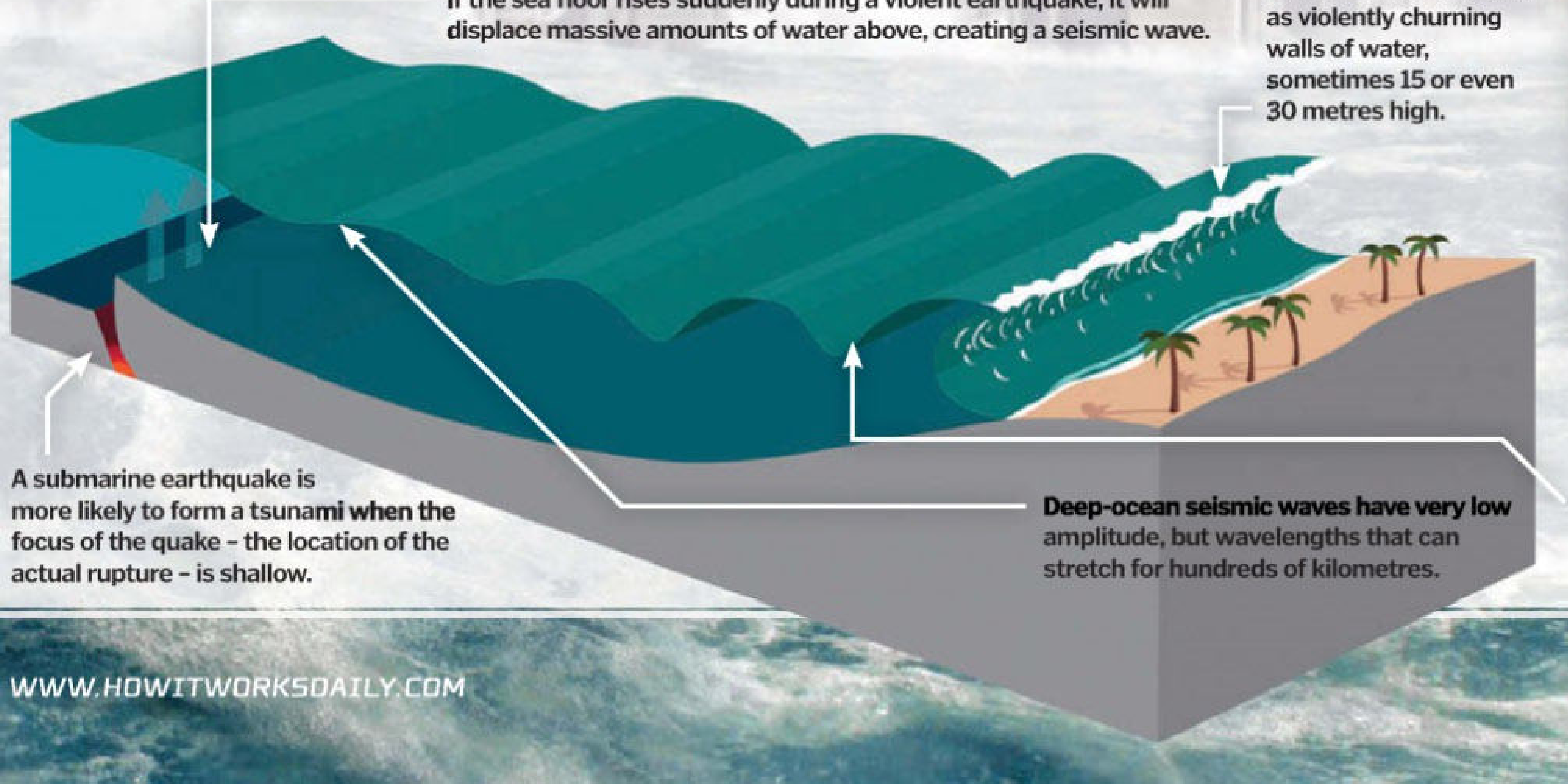
Supercells start like normal thunderstorms. Moist, warm air near the surface is pushed aloft by a physical force like a cold front. The warm air condenses into water droplets as it reaches higher altitudes, forming towering clouds. Supercells grow large because of an abundance of warm, wet air below and cool, dry air above.

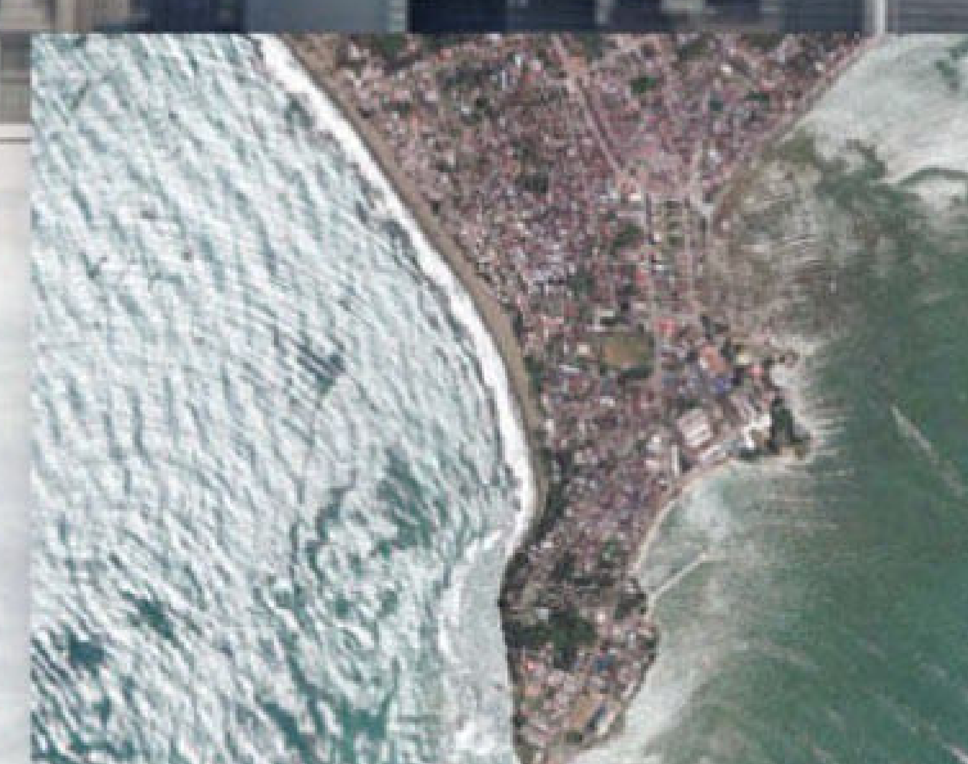
But why do they rotate? It's down to a phenomenon called wind shear, a sudden change of wind speed and direction. Typically, winds blow faster the higher you climb. This creates a paddle wheel effect in the atmosphere, generating columns of air that spin on horizontal axes.

With supercells, the warm, low-lying air is sucked up into the storm with such force that it grabs one of these horizontally rotating columns of air and twists it vertically. The result is a mesocyclone, an intensely rotating column at the heart of the supercell. Meanwhile, rain and hail falling from the supercell are caught in these rotating winds. Much of the precipitation evaporates, releasing pockets of cool air that pull downward on the swirling vortex.

As intensely rotating winds reach the ground, friction slows the effects of centrifugal force, tightening the funnel. There is incredibly low air pressure inside the funnel, which acts like a vacuum. As more and more air is sucked into the vortex, the speed of rotation increases, like a figure skater pulling in her arms for the final head-spinning twirl.

The resulting tornado can generate winds over 300mph, tear through reinforced structures like a buzz saw, lift large vehicles, and flatten homes.





Deadly force

Later waves are usually the deadliest, launching masses of debris on-shore

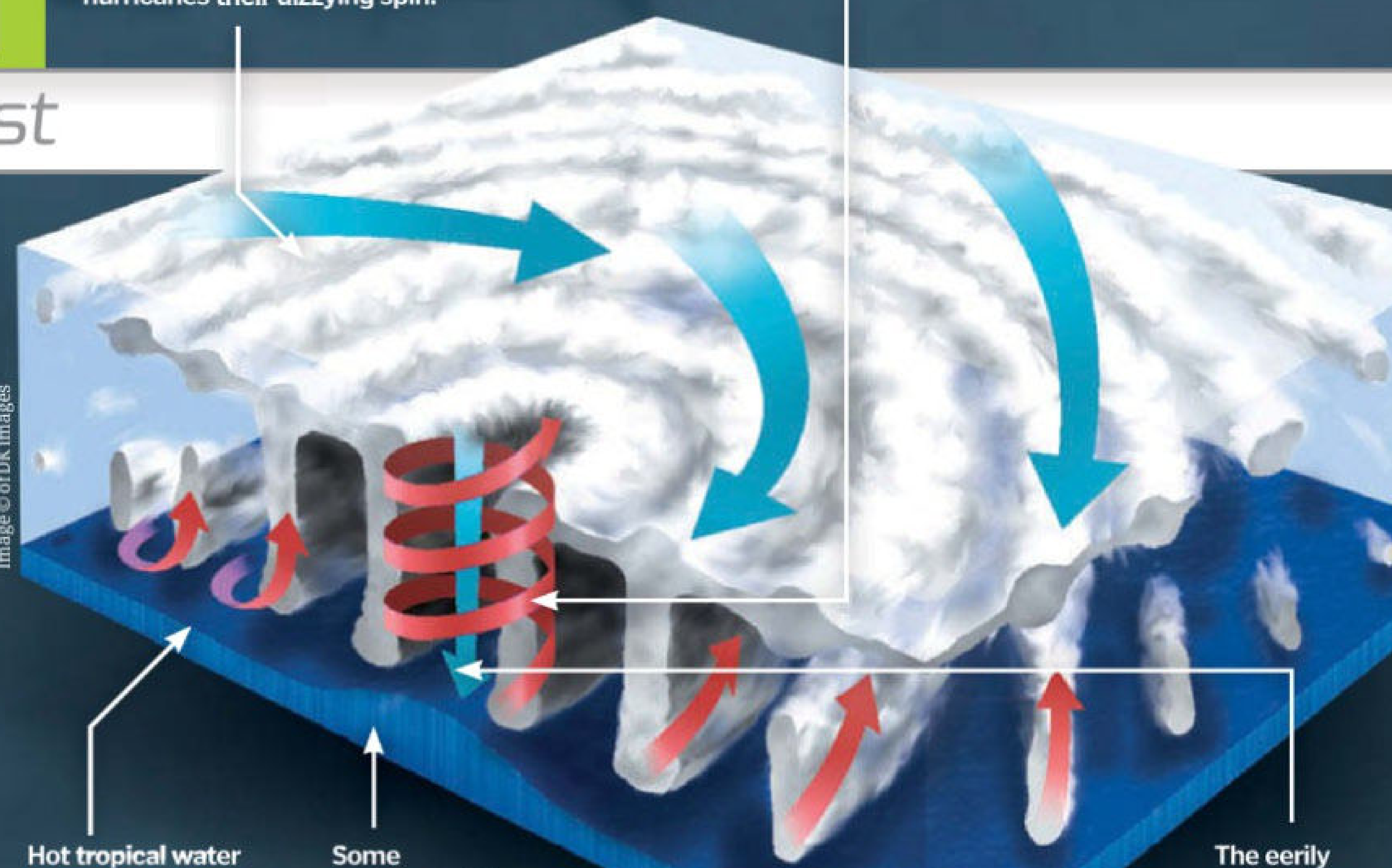
There's a storm coming…

The origins of hurricanes, a deadly force of nature

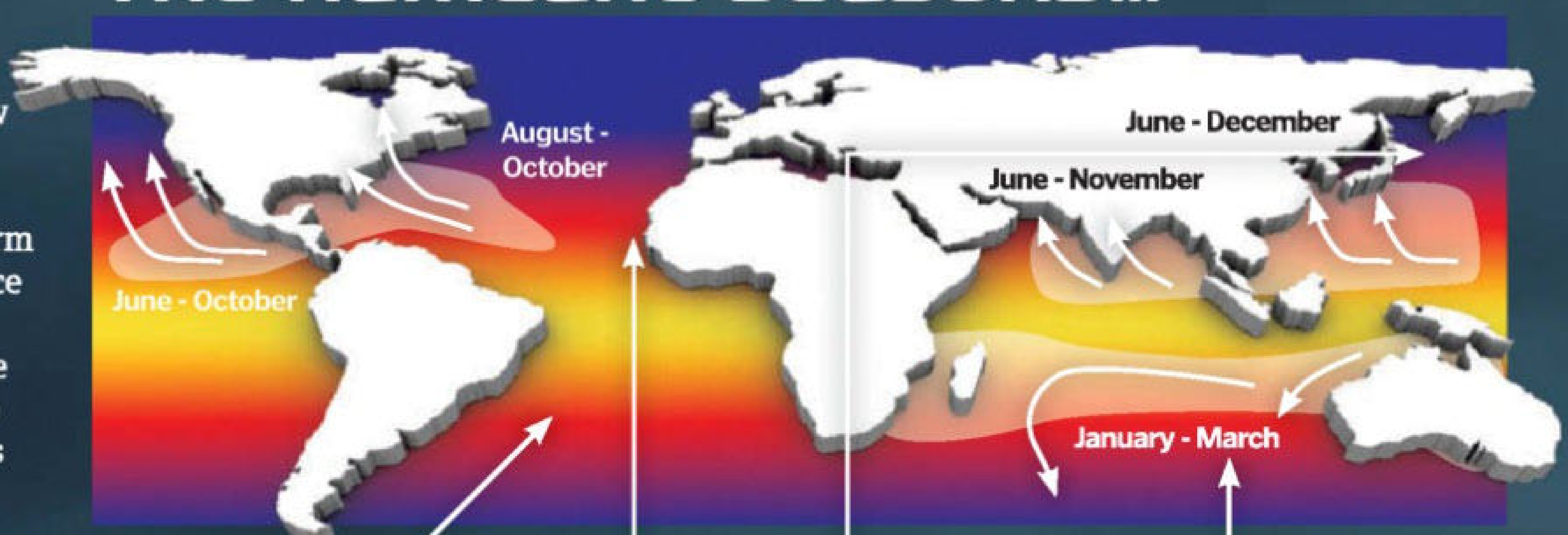
Hurricanes are massive heat engines. They form over tropical waters with a minimum temperature of 27°C (80°F). Hot water evaporates very quickly, rising up through the atmosphere until it condenses into clouds and water droplets. The incredible thing is that condensation itself creates even more heat. The recharged air soars even higher, building a cluster of towering, fat thunderstorms called a tropical disturbance.

Once the heat engine has been jump-started, rapid condensation within the storm continues to force air upward while more hot air rushes in from below to fill the void. This suction of hot air from the ocean surface creates lower and lower air pressure. When air rushes from high pressure to low pressure, it creates powerful winds. When wind velocity reaches 38mph, the storm is called a tropical depression.

Satellite images of hurricanes show a swirling vortex of storm clouds. The spin is caused by two main forces: the Coriolis force and the pressure gradient. In the northern hemisphere, the Earth's rotation pulls winds to the right (Coriolis force), but the extreme low pressure at the storm's centre pulls them back to the left, creating a net counter-clockwise spin. The opposite is true south of the equator. As the heat engine chugs on, more water condenses, more heat rises, the pressure drops further and spin increases until winds reach 39 to 74mph, enough to qualify as a tropical storm. Seven out of ten tropical storms spin even faster than 74mph, officially becoming a hurricane.



The hurricane seasons…



There are few hurricanes in the south Atlantic because high wind shear near the ocean surface shreds tropical storms.

Atlantic hurricanes begin as tropical depressions off the African coast from June to November, when the tropical waters are steamiest.

Hurricanes are called typhoons in the northwest Pacific, and they can occur year-round due to high average water temperature.

October through March is spring and summer in the southern hemisphere, meaning more cyclones (India) and willy-willys (Australia).

Extreme heat
Hundreds of lightning bolts strike the earth every second, each generating temperatures exceeding 27,000°C

DID YOU KNOW? Although the odds of being struck by lightning during a lifetime are one in 3,000, a park ranger in the US survived seven separate jolts before taking his own life.

Thunder and lightning

Beauty has never been so powerful…

Inside the chaos of a storm cloud, falling bits of ice collide with updrafting water droplets, shearing off electrons to create newly charged particles. The negative particles sink to the bottom of the cloud, while positive particles rise to the top, just like a colossal battery. As a storm cloud swells in size, the force of its negatively charged underside repels negative ions away from the surface of the Earth, creating a net positive charge on the ground. Something needs to correct the imbalance between theses huge oppositely charged masses.

Lightning is a violent electrical discharge between clouds and surface objects, clouds and other clouds or points within the same storm cloud. In fact, only ten per cent of lightning strikes hit the earth. Cloud-to-ground lightning begins when a negative charge from the cloud begins to carve a path of least resistance through ionised air, zigging and zagging every 25 meters. When it nears the ground, a positive charge called a 'streamer' reaches up from surface objects, completing the circuit. The resulting strike is instantaneous, travelling at 300 million m/s with the power of 100 billion volts.

A clap of thunder is caused by shock waves created by the expanding and contracting air around the superheated lightning.

The world's most powerful generator

1 If you calculate the total heat generated by condensation inside a hurricane, it equals 200 times our daily worldwide energy-generating capacity.

No-holds-barred Nancy

2 Typhoon Nancy, which tore across Japan in September 1961, clocked sustained winds of 185kph (213mph), the fastest on record.

A four-ce to be reckoned with

3 Only twice in modern history – 1893 and 1998 – did four hurricanes power their way simultaneously through the Atlantic basin.

Another myth down the drain

4 It is untrue that the Coriolis force causes toilets to flush in different directions in the northern and southern hemispheres.

A name to be remembered

5 Since the Fifties, all tropical storms and hurricanes in the Atlantic basin receive a name. If the storm's particularly deadly, the name is retired.

How are blizzards created?

These deadly winter storms can strike without warning

In January 1996, 100 million tons of snow fell on the streets of New York City and nearby Philadelphia was buried under a record 78 centimetres (30.7 inches). Ice storms and sub-zero temperatures stretched as far south as sunny Florida, trapping people in their homes, often without electricity. In 1891, easterly winds dumped 3.6 metres (11 feet) of snow in London. Trains were completely buried under tremendous drifts and 65 ships sank under the heavy ice and snow.

Blizzards form exactly like thunderstorms. A cold front pushes warmer, moist air into the atmosphere, condensing into clouds. If temperatures stay below freezing, snow falls instead of rain. If huge amounts of snow are accompanied by gale-force winds, it's possible to achieve a complete whiteout, when earth and sky merge in a disorienting canvas of white.

DID YOU KNOW? For a winter storm to qualify as a blizzard, there must be sustained winds of at least 58kph (35mph) and less than 0.4 km (0.25 mile) visibility for three hours or more.

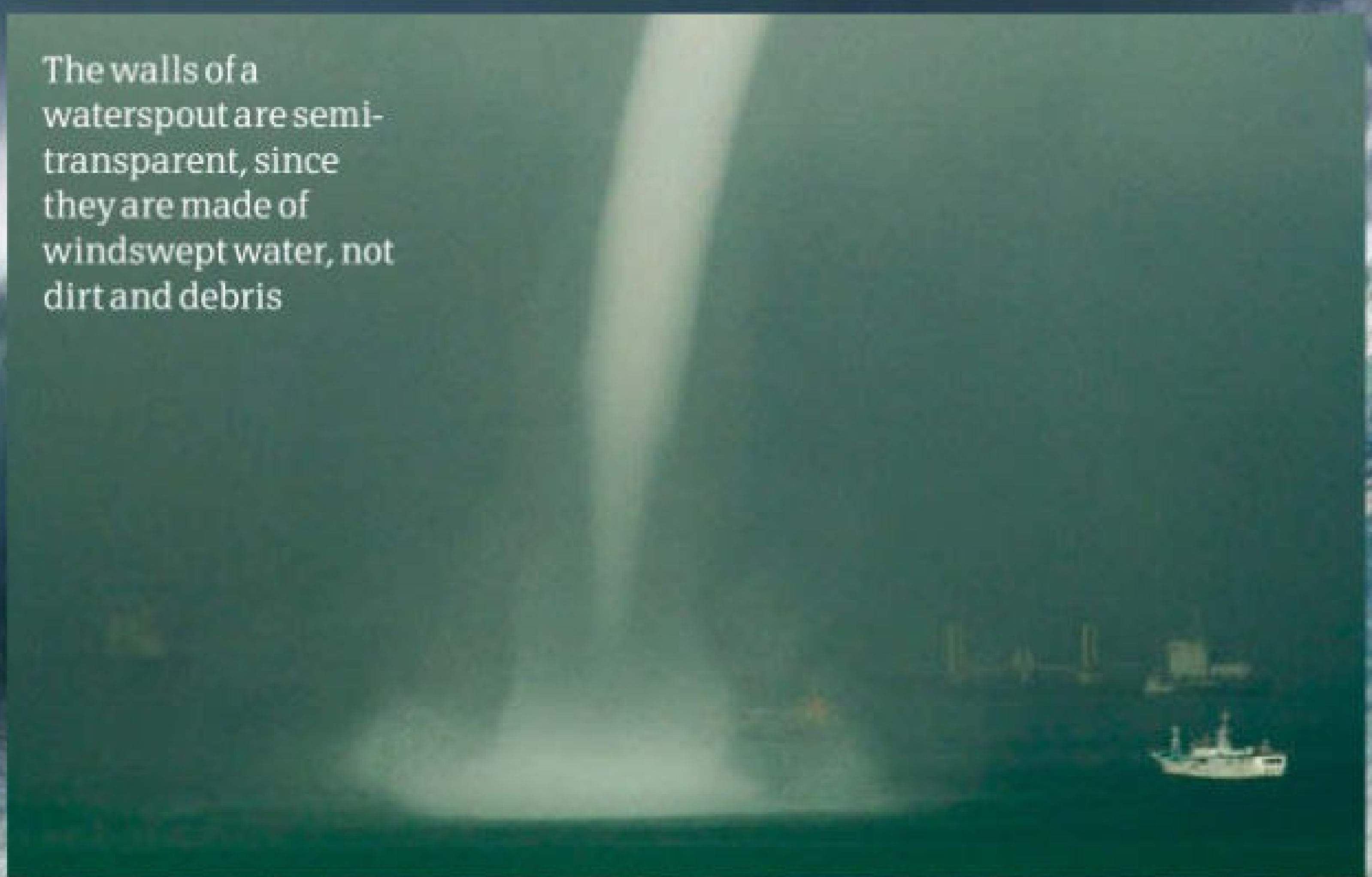
Blanket covering!
You're going to need more than an ice scrapper to get out of this one mate…

Waterspout

While it's never truly rained 'cats and dogs', it has rained frogs and fish. In the past century, towns in the United States, Greece and Serbia have been inundated with falling amphibians (some of them frozen solid) that pile up in the streets. While a Biblical plague isn't out of the question, the more likely culprit is a waterspout, a tornado-like vortex that forms over water.

There are two kinds of waterspouts: tornadic and fair weather. Tornadic waterspouts form under the exact same conditions as tornadoes and can generate winds over 300kph (200mph) with powerful internal updrafts. The low-pressure core of the waterspout can dip several metres under water, sucking up anything in its path, including fish, frogs and lizards. Fair weather waterspouts grow from the ocean up, created by the sudden convergence of smooth and choppy seas. Swirling water is pulled upward by rising air currents, without the help of a major storm system.

While fair weather waterspouts are weak and rarely cause damage, tornadic waterspouts have torn apart ships at sea. Famed waterspout researcher Joseph Golden believes many so-called 'Bermuda Triangle' disappearances are caused by killer waterspouts.



The walls of a waterspout are semi-transparent, since they are made of windswept water, not dirt and debris

Water world
You know you're in trouble when your street looks more like a river than a road

Floods

After the rains, the deluge

When you think of killer weather, you picture tsunami-battered coasts or twisting black tornadoes. But one of the deadliest weather phenomena worldwide is flooding. Flash floods – where small rivers and creeks swell without warning to raging torrents – are the number one weather-related killer in the United States. Flash floods can happen almost anywhere. In cities, there often isn't enough green space to absorb the runoff from a severe storm. This can overwhelm drainage systems, causing flash floods in low-lying areas.

In the mountains, a sudden torrential downpour can feed hundreds of small streams that merge in a single river valley. The result can be dramatic and deadly, creating a wall of churning water – five to ten metres of mud, rocks and debris – that wipes out everything in its path. Violent hurricane winds – gusting over 135kph (155mph) in some cases – can push a mound of water in front of the hurricane called a storm surge. During Hurricane Katrina, powerful surges breached the levee system, causing widespread destruction by flooding.

The 2007 floods in the UK were an example of river flooding caused by sustained, powerful rains. Over the course of 12 hours, parts of northeast England received a sixth of their annual rainfall, swallowing whole towns in swollen rivers.

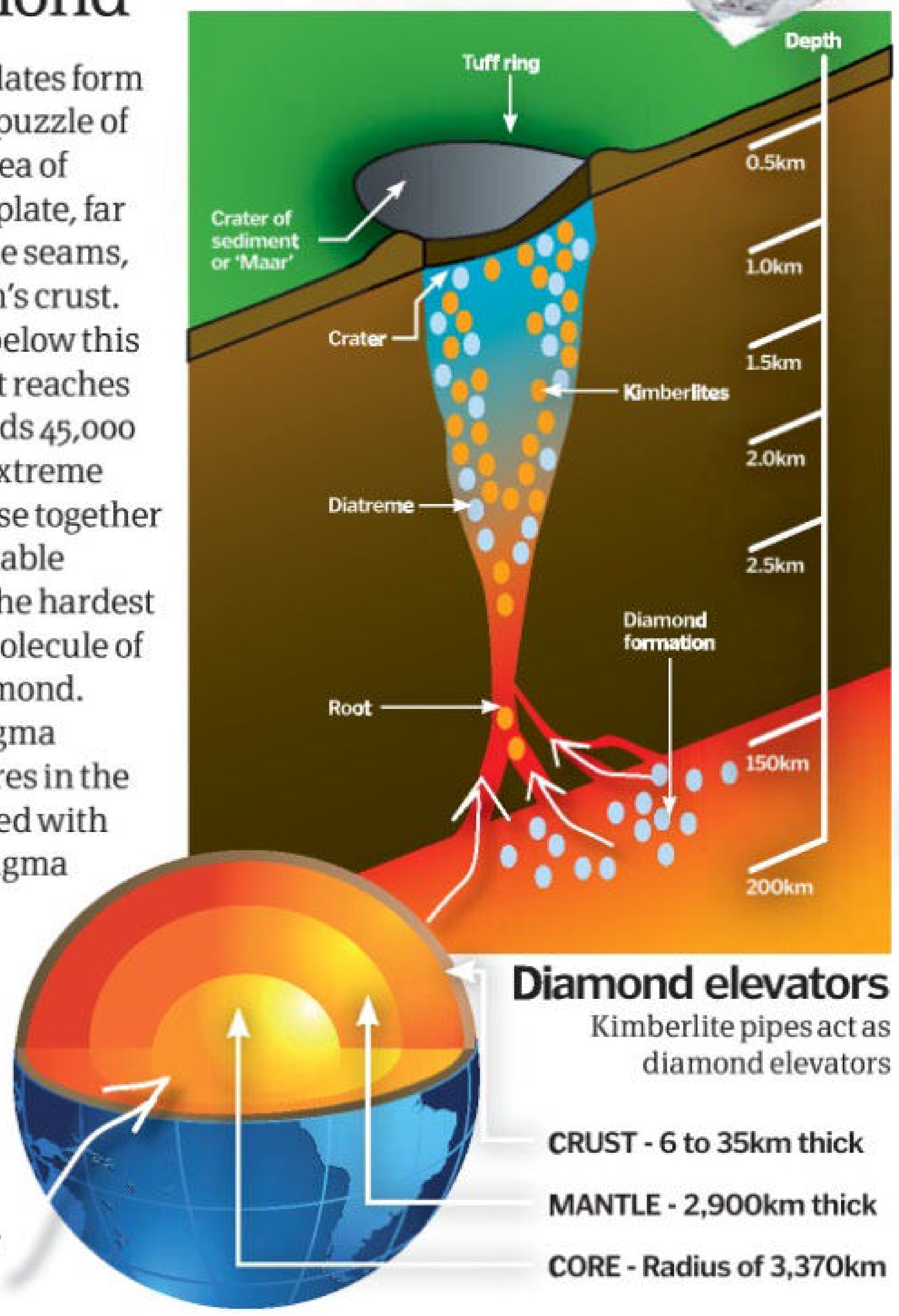
Diamonds take forever

It takes the weight of the world to make a diamond

The Earth's tectonic plates form an impressive jigsaw puzzle of solid rock adrift on a sea of magma. In the middle of each plate, far from the volcanic ring along the seams, lies the oldest rock in the Earth's crust.

Amazingly, 160 kilometres below this colossal heap of stone, the heat reaches 1,200°C and the pressure exceeds 45,000 kilograms/cm2. Under these extreme conditions, atoms of carbon fuse together in covalent bonds, an unbreakable chemical union. The result is the hardest substance on earth, a single molecule of pure carbon that we call a diamond.

Millions of years ago, as magma pushed upward through fissures in the crust, it carried rocks embedded with diamonds. Sometimes, the magma cooled in carrot-shaped underground formations called Kimberlite pipes. Modern diamond mines now burrow through these rich geological rarities.



Diamond elevators
Kimberlite pipes act as diamond elevators

Diamonds are formed in the upper mantle, 160km below the surface

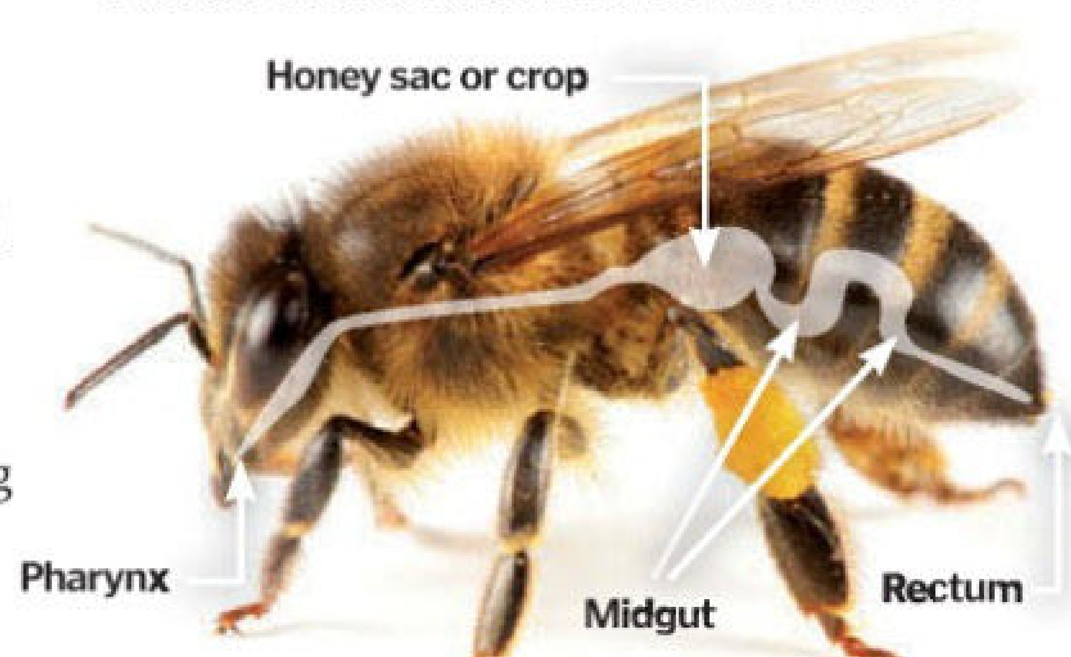
How do bees make honey?

It's up to thousands of industrious insects to sweeten your tea

Honey begins its journey as nectar, the sugar water produced by flowers. Worker bees visit up to 1,500 flowers a flight, sucking nectar through straw-like tubes and storing it in their honey sacs.

The honey sac or crop contains an enzyme that breaks down the nectar's complex sugars into glucose and fructose, which are easier for the bees to digest and make the sweet liquid less hospitable to bacteria and fungi. In the hive, more worker bees draw the nectar from the honey sacs, 'chew' it for further processing and deposit drops of the precious liquid in honeycomb cells.

What happens next is wonderfully weird. Teams of worker bees positioned throughout the hive fan their wings furiously, increasing air circulation to speed up the evaporation process. When the nectar's reduced from 80 per cent water to only 18.5 per cent, it is officially honey, and the cells are sealed over with wax.



The honey sac stores nectar outside of the stomach

How do snakes bite?

Call them cold-blooded, but snakes have death down to a science

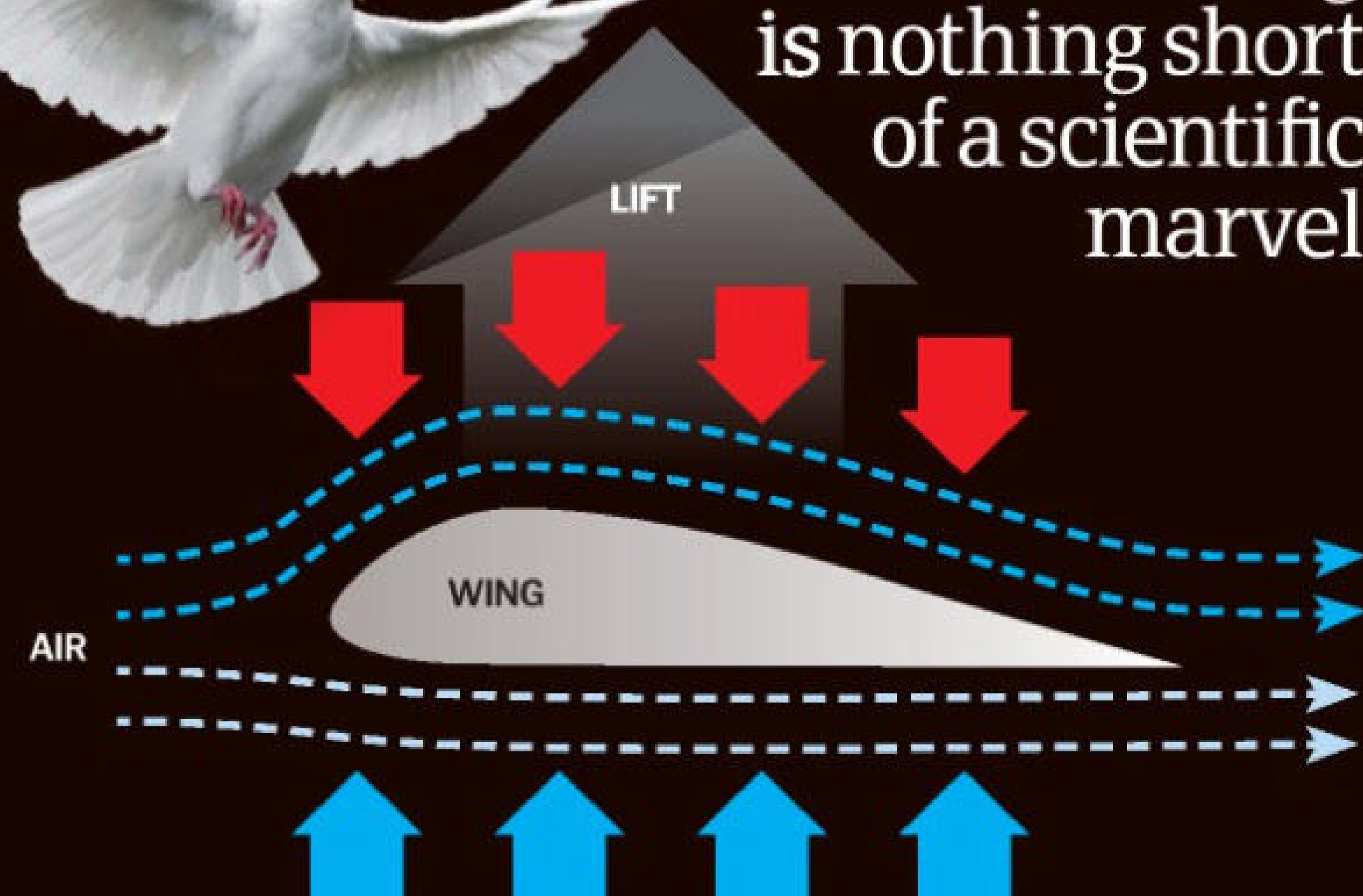
Snakes are highly adapted killers. Non-venomous snakes kill by constriction (suffocation) or swallowing prey alive. Venomous snakes – which make up only ten per cent of the world's snake species – inject their victims with powerful toxins that either paralyse the respiratory system or attack red blood cells, instantly rotting flesh and bone.

Only venomous snakes have fangs, a set of long, hollow teeth in either the front or back of the mouth that act as hypodermic needles. As fangs enter the flesh, the snake flexes its jaw muscle, squeezing toxic saliva out of the venom gland, through the fang's venom canal and deep into the victim's tissue.

Snakes can control the release of venom, so many defensive strikes against humans are non-lethal 'dry bites'. If bitten, never try to cut open the wound or suck out the venom. Keep the victim calm and get to a hospital quickly for a dose of antivenin.

Birds' wings explained

The bird wing is nothing short of a scientific marvel



Some birds can live their entire lives aloft, even soaring while sleeping. Others migrate thousands of kilometres. The real miracle is the wing itself, a singular feat of evolutionary engineering.

When outstretched for gliding, bird wings form a perfect aerofoil, a surface that is curved on top and flat on the bottom. According to Bernoulli's principle, air travels faster across the curved upper surface, lowering air pressure above the wing and generating lift.

Aeroplane wings require separate engines, but bird wings provide both lift and thrust. During flapping flight, birds are essentially 'rowing' through the air, pushing down and back powered by two thick layers of pectoral muscles.

Wing feathers grow in separate sections that shift position and overlap to provide a smooth curved surface for maximum lift. On an upstroke, contoured flight feathers collapse along a rigid shaft, minimising the resistance, then expand on the downstroke, maximising thrust.

DEADLIEST
Inland Taipan
Habitat: Australia
Mortality Rating: 100 per cent without immediate antivenom
Fact: 750 times more venomous than a cobra

DEADLIER
Papuan Taipan
Habitat: New Guinea
Mortality Rating: 100 per cent without antivenom
Fact: Nearly as toxic as its Aussie cousin

DEADLY
Blue Krait
Habitat: Australia
Mortality Rating: 50 per cent even with antivenom
Fact: Nocturnal, and is more aggressive during the night

DID YOU KNOW? Ozone was originally discovered and named by Christian Friedrich Schönbein in 1840

The ozone layer explained

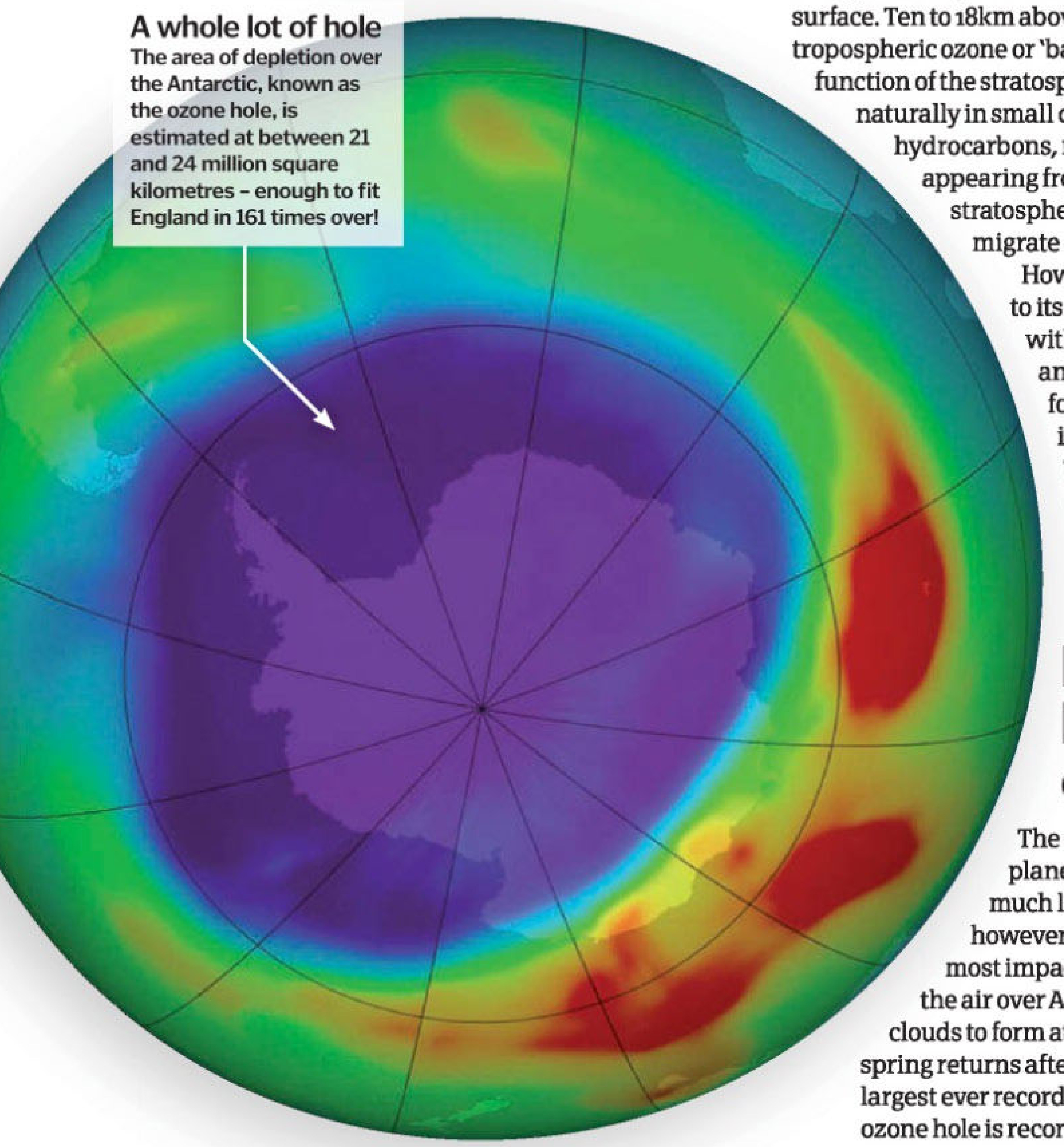
We may hear about it a lot, and mainly how we're slowly destroying it, but just what is the ozone layer?

The ozone layer is essentially Mother Earth's safety net, residing some 50 kilometres above the planet's surface. Created from O3, or ozone gas, it is up to 20 kilometres thick and 90 per cent of this gas can be found up on the Earth's stratosphere. This protective gas is vital to the nurturing of life on our planet, and here's why.

Ozone gases act as a shield against ultra violet, or UVB, radiation. These harmful emissions are sent through the Sun's rays, and without the ozone would severely affect the planet's ecological balance, damaging bio-diversity. UVB rays reduce plankton levels in the ocean, subsequently diminishing fish stock. Plant growth would also diminish in turn disrupting agricultural productivity. This would in turn affect the human populace, who would be exposed to an increase in skin-related diseases such as cancer.

So how does the ozone protect us? Ozone molecules consist of three oxygen atoms, hence the chemical formula O3. Stratospheric ozone absorbs UVB high-energy radiation, as well as energetic electrons, which in turn splits the O3 into an O atom and an O2 molecule. When the O atom soon encounters another O2 molecule they re-merge and recreate O3. This means that the ozone layer absorbs the UVB without being consumed. The ozone layer absorbs up to 99 per cent of the Sun's high frequency UV light rays, transforming this into heat after its combustible atomic reaction, therefore creating the stratosphere itself. This effectively incubates life on Earth.

But ozone doesn't reside only in the world above. This gas is also present in the layer around the Earth's surface. Ten to 18km above us, this is known as the tropospheric ozone or 'bad ozone', comparative to the function of the stratosphere. This ozone occurs naturally in small doses, initiating the removal of hydrocarbons, released by plants and soil, or appearing from small amounts of stratospheric ozone, which occasionally migrate down to the Earth's surface. However, it gets a bad reputation due to its interaction of ultraviolet light, with volatile organic compounds and nitrogen oxides, emitted by fossil-fuel powered machines and internal combustion engines. This produces high levels of ozone, which are formed in high temperature conditions, ultimately toxic to all forms of organic life.



A whole lot of hole
The area of depletion over the Antarctic, known as the ozone hole, is estimated at between 21 and 24 million square kilometres – enough to fit England in 161 times over!

How big is the hole in the ozone layer?

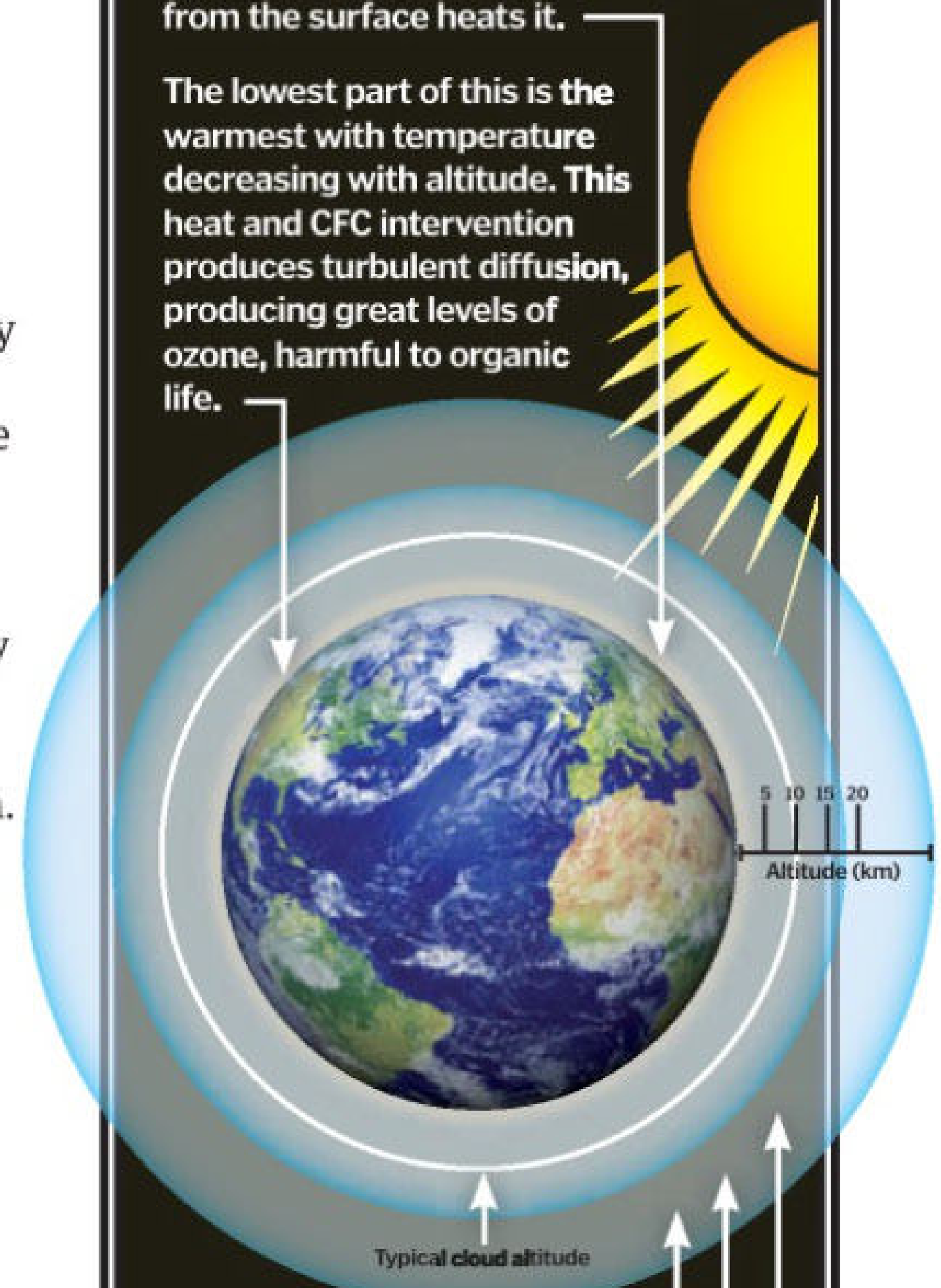
The ozone hole refers to an area of depletion over the Antarctic region of Earth. The planet's ozone records a decline of four per cent per decade in total volume but much larger loses are recorded in the stratospheric ozone over Earth's polar region, however this is seasonal condition. These areas' unique atmospheric conditions see the most impact. Strong winds blow around the continent forming a polar vortex, isolating the air over Antarctica from the rest of the world. This allows special polar stratospheric clouds to form at about 80,000 feet altitude. These concentrate atmosphere pollutant. When spring returns after the sunless winter period the ozone is depleted causing the ozone hole. The largest ever recorded ozone hole occurred in 2006, at 20.6 million square miles. At present the ozone hole is recorded at between 21 and 24 million square kilometres.

The structure of the Earth's atmosphere

Here's how the ozone extends from the Earth's surface

Tropospheric ozone
Starts at ground level, with an altitude of up to 15 kilometres. Energy transfer from the surface heats it.

The lowest part of this is the warmest with temperature decreasing with altitude. This heat and CFC intervention produces turbulent diffusion, producing great levels of ozone, harmful to organic life.



Stratospheric ozone
Between ten and 50 kilometres up from the stratopause. It contains up to 90 per cent of Earth's ozone.

The stratosphere contains the highest level of ozone on the planet, with two to eight parts per million. This reacts with UVB to produce what we know as the ozone layer.

The stratosphere is layered in temperature due to UVB absorption. Heat increases with altitude, with the top of the stratosphere has a temperature up to -3°C.

THE STATS GREAT WHITE

WEIGHT >up to 5,000 pounds
LENGTH >13-23ft (4-7m) SPEED >15mph

The ultimate hunting machine

Exploring great white shark hunting habits

One of nature's deadliest hunters in action

The great white shark, or Carcharodon carcharias, can only be described as the largest predatory fish in the sea. But is this aquatic marauder as fearsome as the popular media would have us believe?

It's certainly a species long in the tooth, in more ways than one. Firstly each of its incisors is a perfect cutting implement, triangularly serrated on both sides. These can grow up to as long as three inches. Upon maturity an adult great white can have anywhere up to 3,000 teeth jam-packed within its gaping jawline.

The way in which this and its teeth operate accordingly is truly remarkable. The great white shark has a floating jaw, enabling it to hold onto its prey with the lower part, as the upper jaw clamps down, tearing away flesh. Couple this with great white sizes reported up to as big as 20-feet or more, carrying weight of up to 2,240 kilograms, or 4,938lb, and that's one killer bite.

The great white's anatomy almost contradicts itself. With a torpedo-shaped torso, it propels itself with its powerful tail, reaching speeds up to 15 miles per hour. These sharks move much like aircrafts, less like conventional swimming fish species. Yet this momentum is used at an advantage, and the great white shark shows strategy in swiftly surprising prey from below. This usually consists of inflicting a fatal bite, which will sees its prey either die of shock or massive body trauma.

It's apparent that this species of shark has evolved into a remarkable hunting machine, quite literally the bloodhound of the sea. The great white has developed the most diverse array of sensors of any known predator.

Hunting techniques

How great whites track and catch their prey

1. Smelly vision
A super sense of smell is the primary detector for the shark species when hunting prey. The great white can amazingly smell a single drop of blood in 100 litres of water.

2. Electric impulse
Jelly-filled canals in the shark's head help detect electrical charges as small as 0.005 microvolts. Enough to detect the heartbeat of hiding fish.

3. Super hearing
Rapid, irregularly pulsed, broadband sounds at frequencies below 600 hertz, made by injured prey and spawning fish, can alert hunting sharks from over one mile away.

4. Touch-at-distance
A row of fluid-filled sensory canals on either side of the body respond to changes in pressure and movement, helping it feel the presence of objects in the water.

5. Swallow or spit
The great white shark has advanced taste receptors located on the swellings in the mouth and gums. These help determine the palatability of its food.

"Volcanoes are evidence of the inner workings of plate tectonics"

Head to Head

Which is the biggest, fastest, strongest?

TALLEST

1. Mauna Loa
Location: Hawaii, USA
Height: At 17km (56,000ft) above its submarine base, Mauna Loa is not only the world's tallest volcano, but arguably the world's tallest mountain.
Last eruption: In 1984, after a series of earthquakes, rifts along Mauna Loa's flanks oozed slow-moving lava for three weeks, threatening the town of Hilo.

BIGGEST ERUPTION

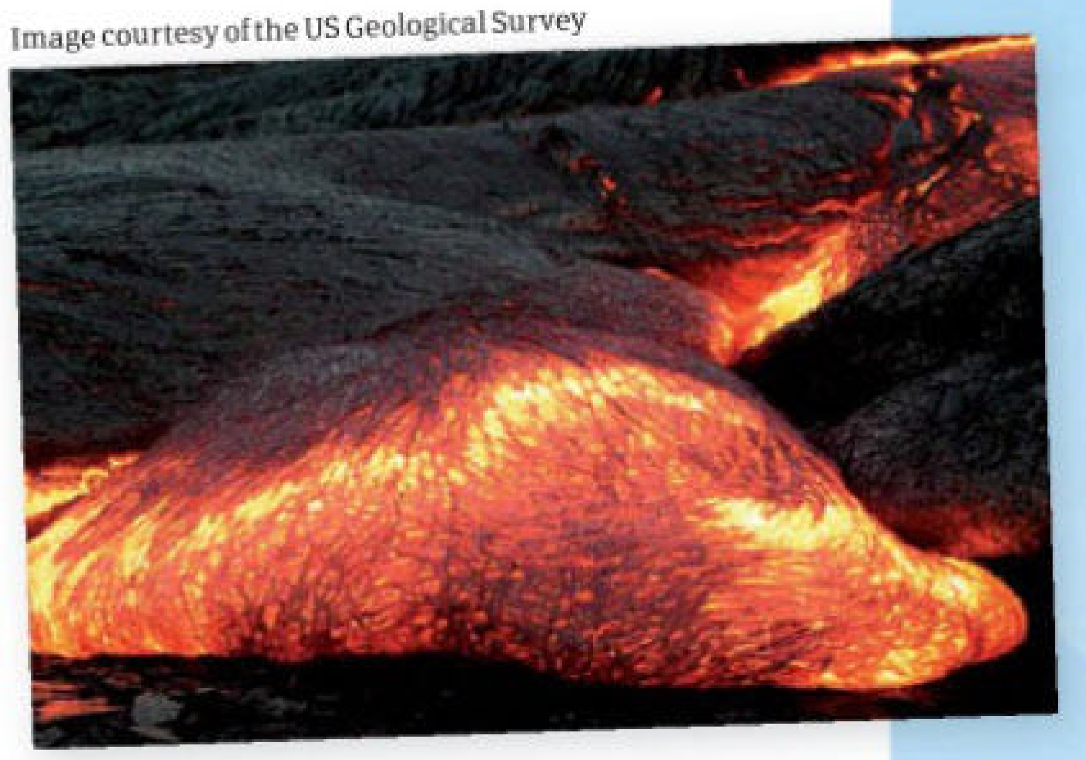
2. Tambora
Location: Sumbawa, Indonesia
Height: 2,859 meters (9,348ft), but was 4,000 meters (13,000ft) prior to 1815
Last eruption: Tambora's 1815 eruption is the largest in recorded history, emitting 150 times more ash than Mt St Helens, killing 92,000 people and creating a worldwide 'year without a summer'.

DEADLIEST

3. Nevado del Ruiz
Location: Colombia
Height: 5,321 meters (17,453ft)
Last eruption: In 1985, a relatively small volcanic eruption melted a thick snow and ice cap, creating a killer lahar (mudslide) that descended on the village of Armero. A 30-metre high wall of water and debris killed over 20,000.

Feeling hot, hot, hot
The temperature of lava can range from anything between 700 and 1,300°C

Image courtesy of the US Geological Survey



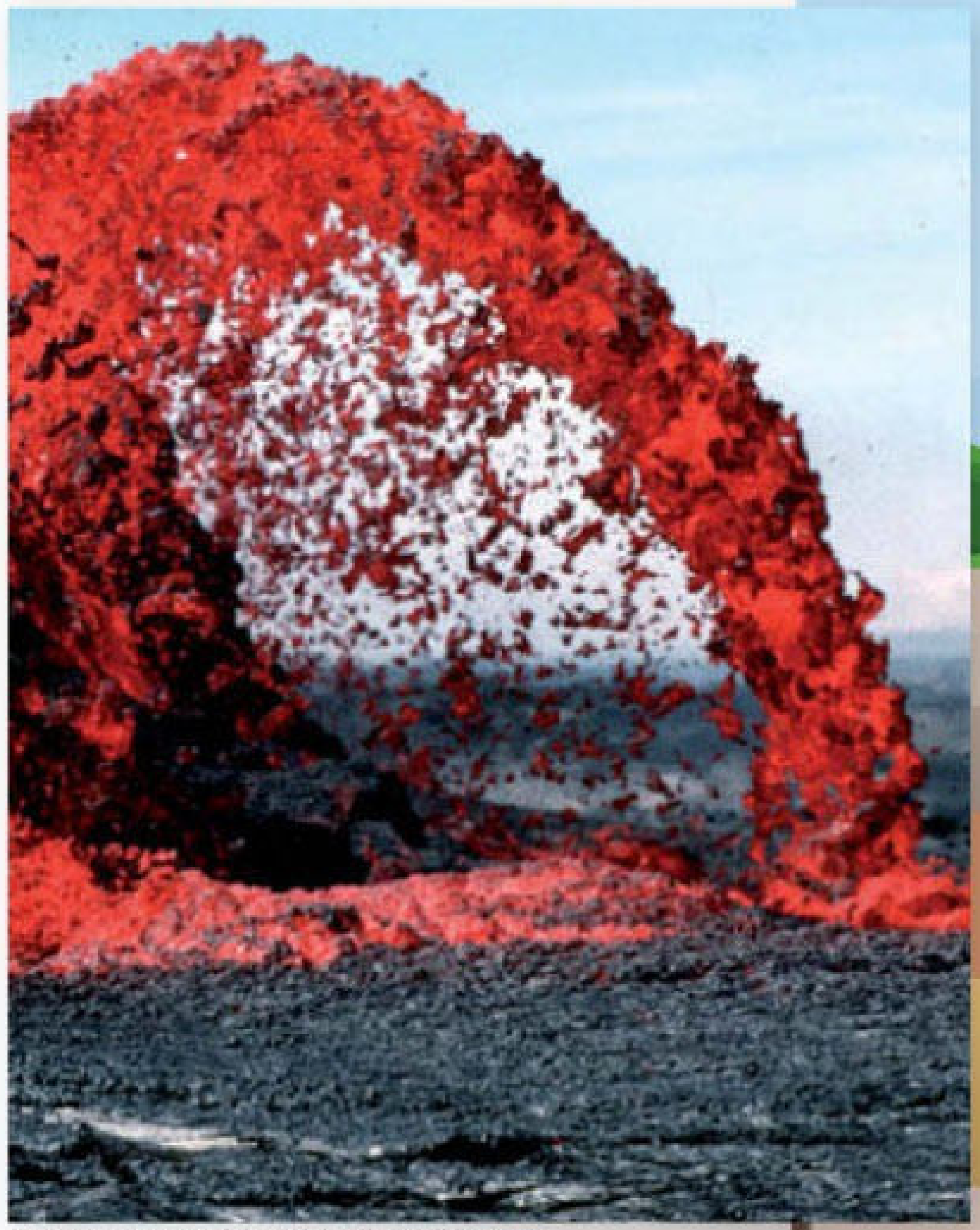
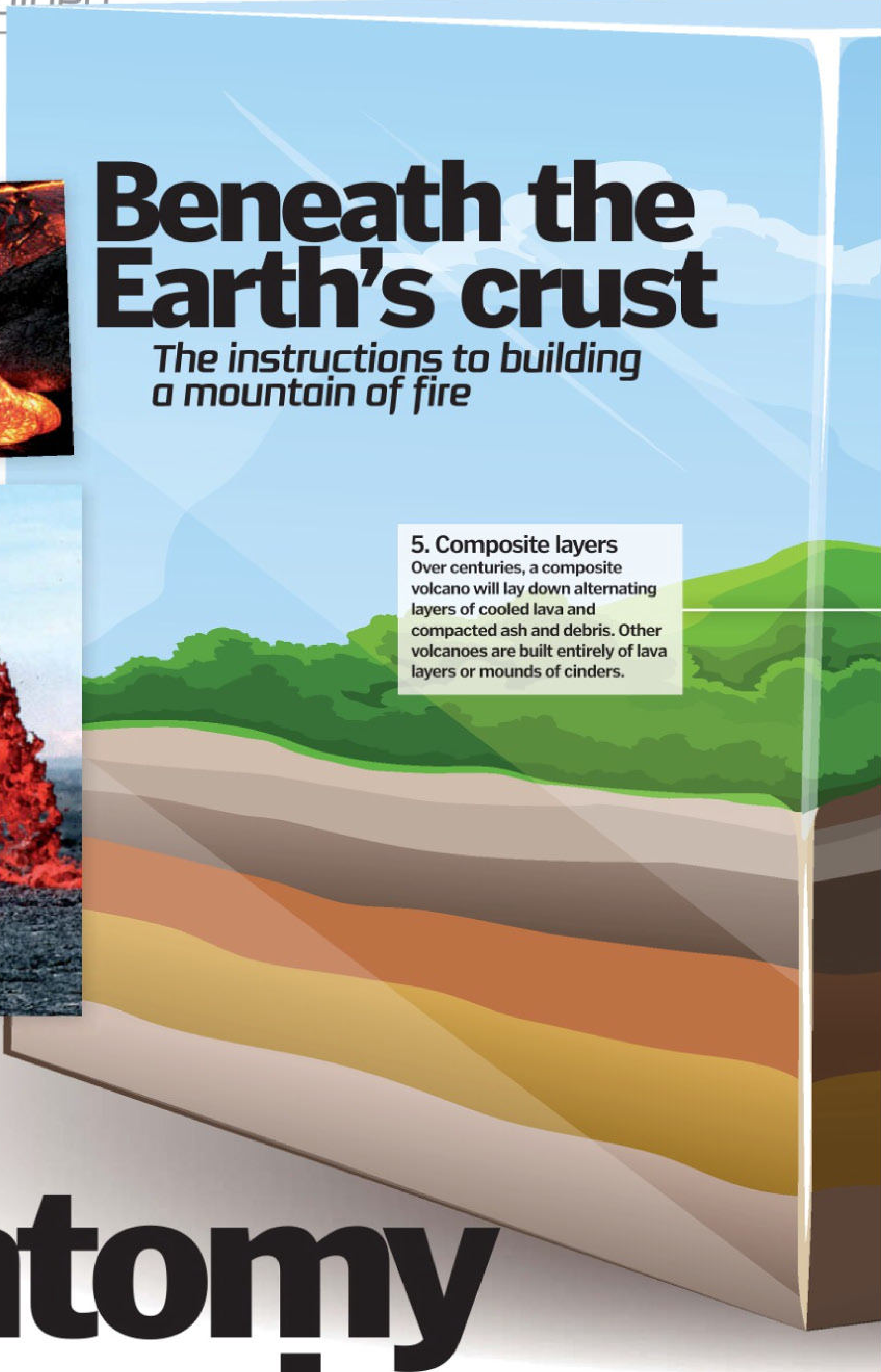


Image courtesy of the US Geological Survey

The wow factor
Although deadly, an erupting volcano is one of nature's most stunning sights

Beneath the Earth's crust

The instructions to building a mountain of fire



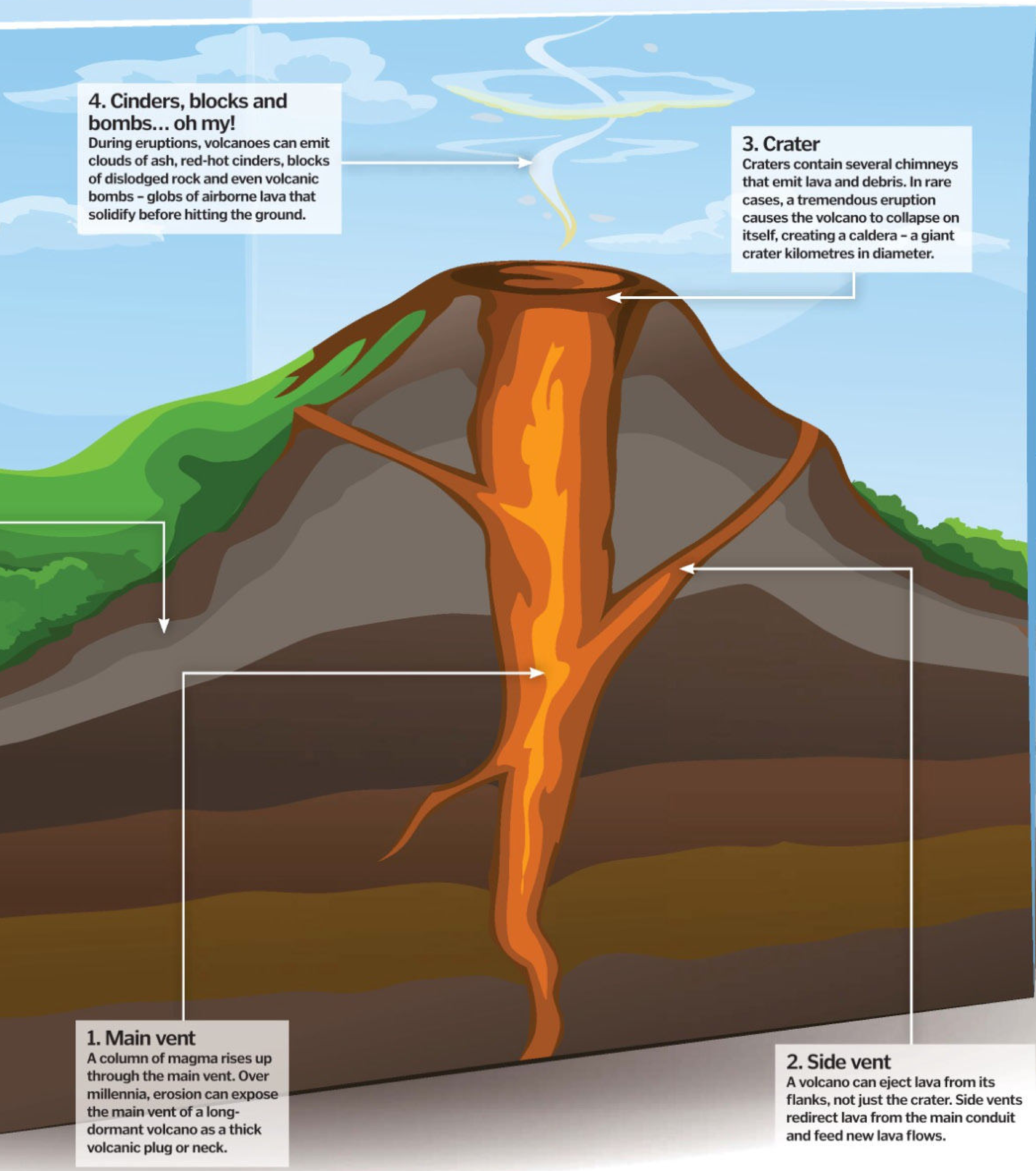
Anatomy of a volcano

Volcanoes are rare locations on the Earth's crust where molten rock (magma) spews to the surface as lava, often accompanied by superheated gas and debris.

Geologists see volcanoes as outward evidence of the inner workings of plate tectonics, the theory that the crust is fragmented into 15 oceanic and continental plates that diverge, converge and slide beneath one another over time.

Approximately 400 of Earth's 500 known active volcanoes lie atop subduction zones, places where an oceanic plate slips beneath another oceanic or continental plate. The 'Ring of Fire' traces a circle of highly active subduction zones around the Pacific Ocean.

In a subduction volcano, magma is formed 100 to 200km beneath the surface when water and carbon dioxide seep from the sinking oceanic shelf, lowering the melting point of the



Breathtaking and often devastating reminders that the Earth's surface is actively evolving

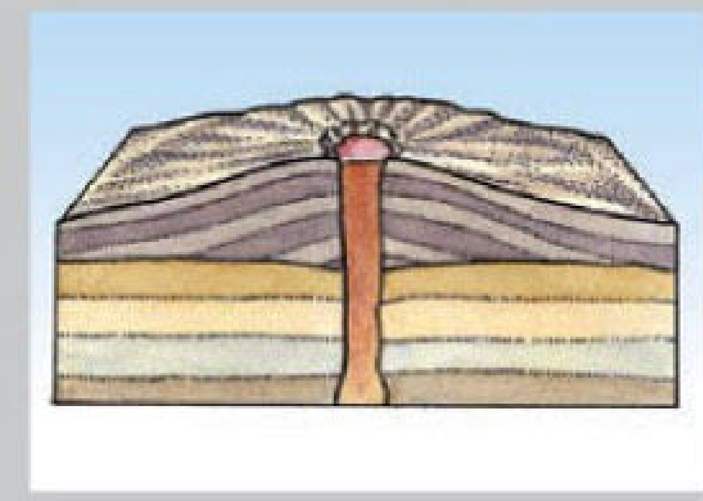
surrounding rock. This fresh magma, which is lighter than solid rock, percolates upward through fissures in the crust, eventually exploding to the surface when trapped gases in the magma rush to escape.

Rift volcanoes form along the great seams of two separating plates. The mid-Atlantic ridge, which separates the North American and African plates, is one of these seams. As the plates pull apart, magma bubbles up through hundreds, even thousands, of small volcanoes to fill the cracks, creating new ocean floor.

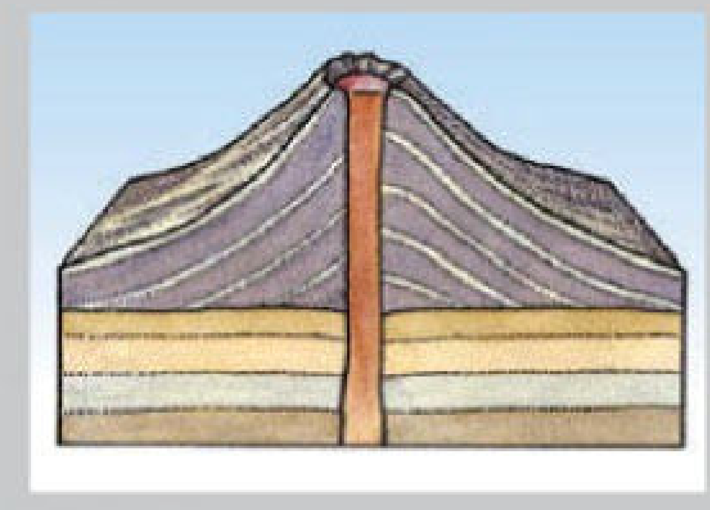
Five per cent of volcanoes are located far from the seams of tectonic plates. So-called hot spot volcanoes are fuelled by deep sources of magma pumped to the surface through powerful convection currents in the molten mantle. Since the deep fuel source remains fixed while the plate slides above, the result is often a string of volcanoes like the Hawaiian Islands.

TYPES OF… Volcanoes

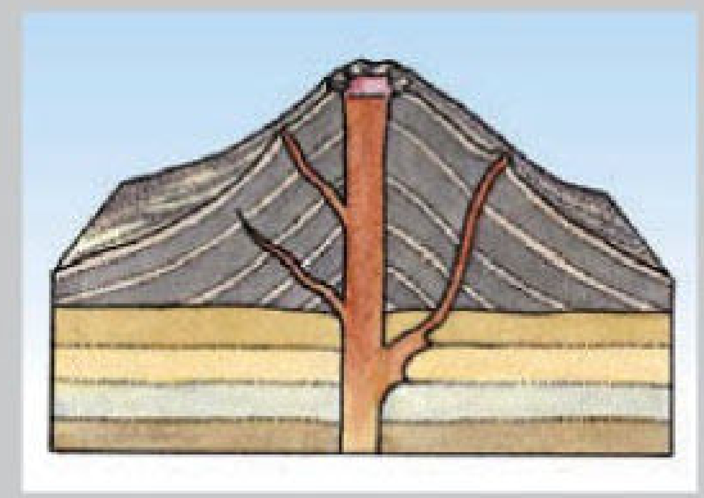
Volcanism takes the shape of towering peaks and flat plateaus



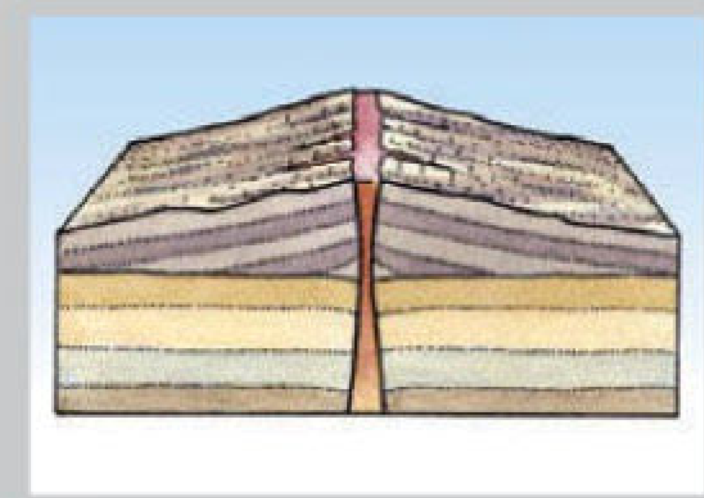
Shield
Wide, shallow-sloped volcanoes formed by layers of slow-oozing lava (Mauna Loa in Hawaii).



Cinder
Small, single-vent volcanoes composed of a pile of shattered volcanic rock and ash (Paricutín in Mexico).



Composite
Tall, steep-sloped volcanoes made from alternating layers of cooled lava and debris like ash and lava bombs (Mt Fuji in Japan).



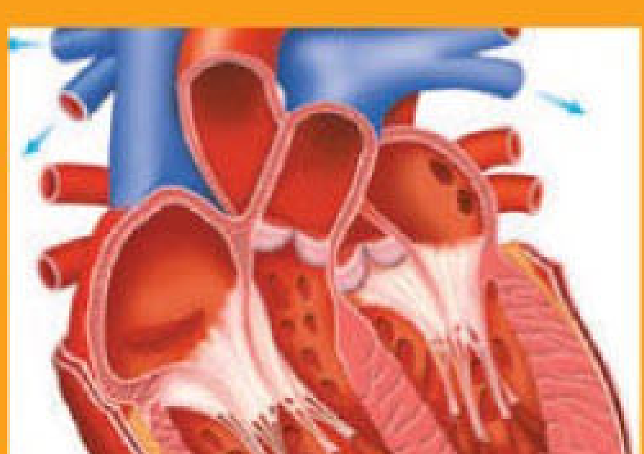
Fissure
Flat fields of lava that emerge from long cracks along the Earth's rift zones (Las Pilas in Nicaragua).

Learn more

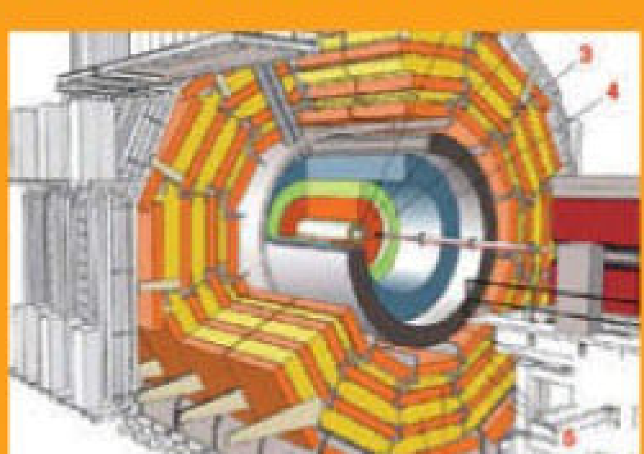
For more information about volcanoes visit **www.avo.alaska.edu**, the official website of the Alaska Volcano Observatory, where you can see videos and live webcams of all the active volcanos in Alaska.

This month in **Science**

Welcome to the science section where you can find investigations and explanations of the application of science in the contemporary world. The largest and most expensive science experiment in the world, the Large Hadron Collider starts again in November, coinciding perfectly with our launch issue. You can find out how it was repaired on page 34.



29 Your heart explained

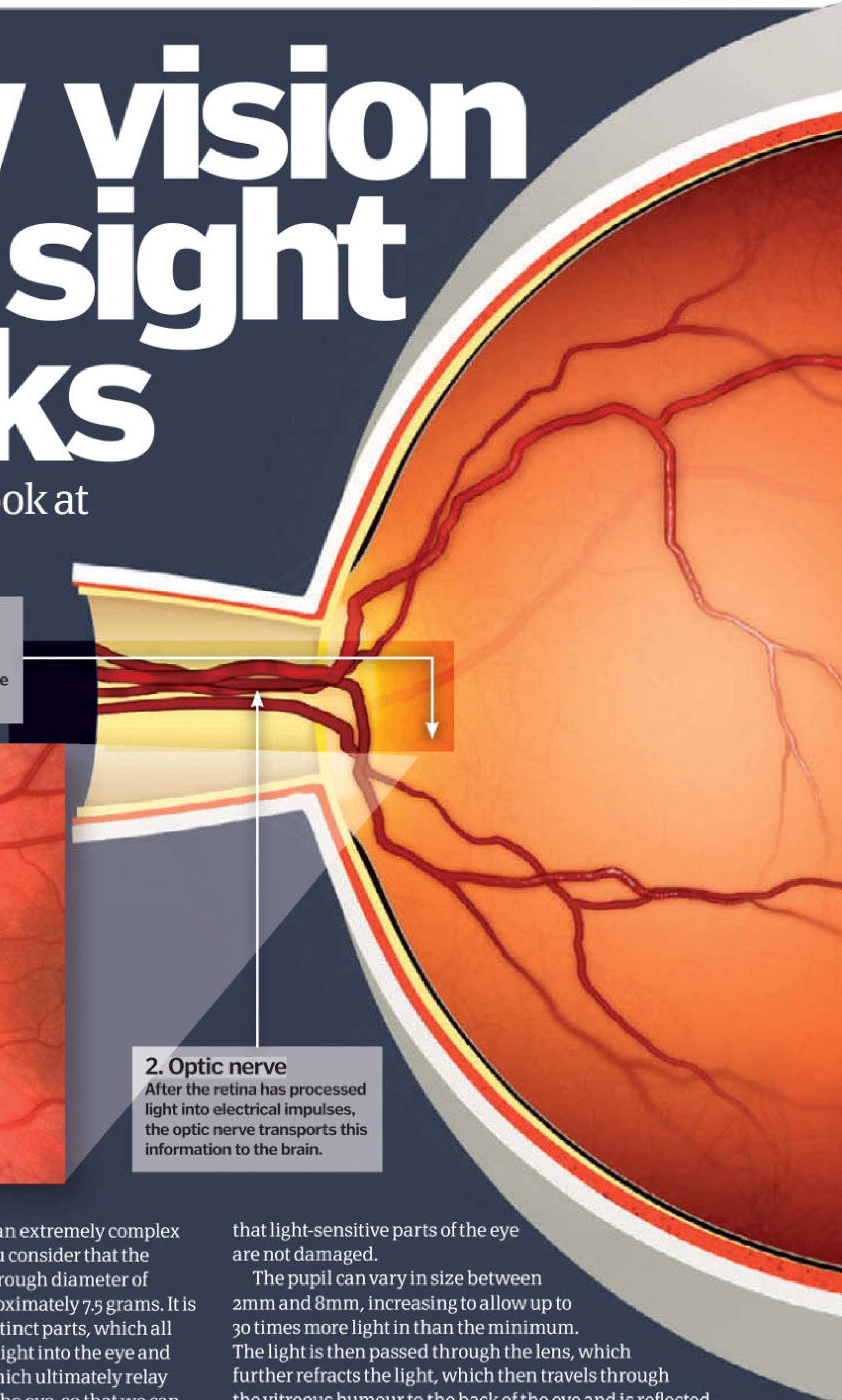


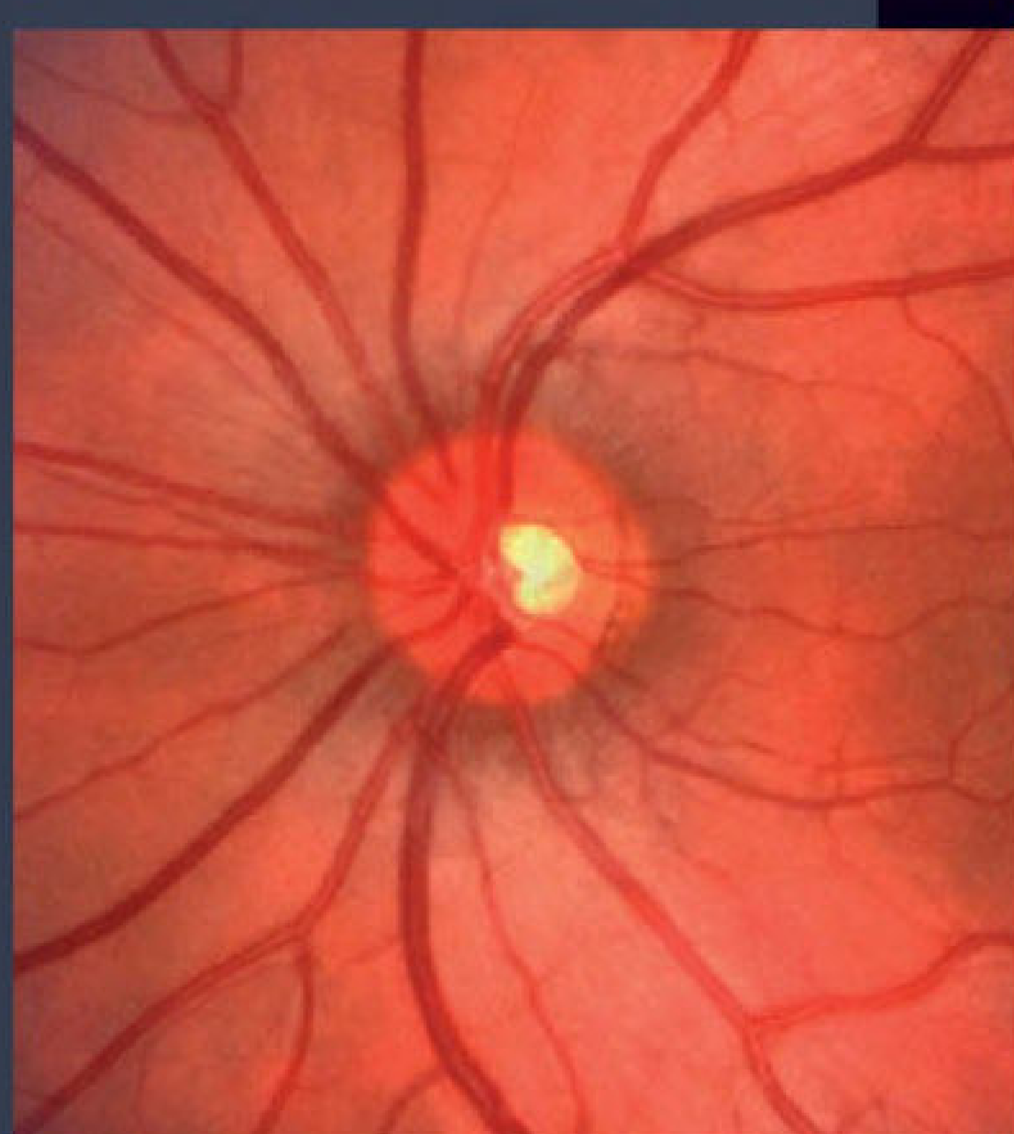
34 The LHC returns

SCIENCE

How vision and sight works

An eye-opening look at how we see…





The biology of the eye is an extremely complex one, especially when you consider that the human eye only has the rough diameter of 2.54cm and weighs approximately 7.5 grams. It is made up of around 15 distinct parts, which all have different roles to play in receiving light into the eye and transmitting the electrical impulses, which ultimately relay image information to our brains, out of the eye, so that we can perceive the world we live in.

The eye is often compared to a basic camera, and indeed the very first camera was designed with the concept of the eye in mind. We can reduce the complex process that occurs to process light into vision within the eye to a relatively basic sequence of events. First, light passes through the cornea, which refracts the light so that it enters the eye in the right direction, and aqueous humour, into the main body of the eye through the pupil. The iris contracts to control pupil size and this limits the amount of light that is let through into the eye so that light-sensitive parts of the eye are not damaged.

The pupil can vary in size between 2mm and 8mm, increasing to allow up to 30 times more light in than the minimum. The light is then passed through the lens, which further refracts the light, which then travels through the vitreous humour to the back of the eye and is reflected onto the retina, the centre point of which is the macula.

The retina is where the rods and cones are situated, rods being responsible for vision when low levels of light are present and cones being responsible for colour vision and specific detail. Rods are far more numerous as more cells are needed to react in low levels of light and are situated around the focal point of cones. This focal gathering of cones is collectively called the fovea, which is situated within the macula. All the light information that has been received by the eye is then converted into electrical impulses by a chemical in the retina

5 TOP FACTS THE EYE

Independent evolution across species

1 Convergent evolution has produced a very similar eye across species; mammals and cephalopods' common ancestor had a photoreceptive spot.

8% of males can't see green

2 Or red! X chromosome-inherited mutations can lead to colour blindness, the most common of which is red/green colour blindness.

Hawks have 20/2 vision!

3 Hawks have up to eight times better vision than the average human due to increased levels of cones and rods in the eye.

Your eyes don't get tired

4 The eye is the only organ of the body which doesn't actually need rest. It can operate at 100 per cent all the time.

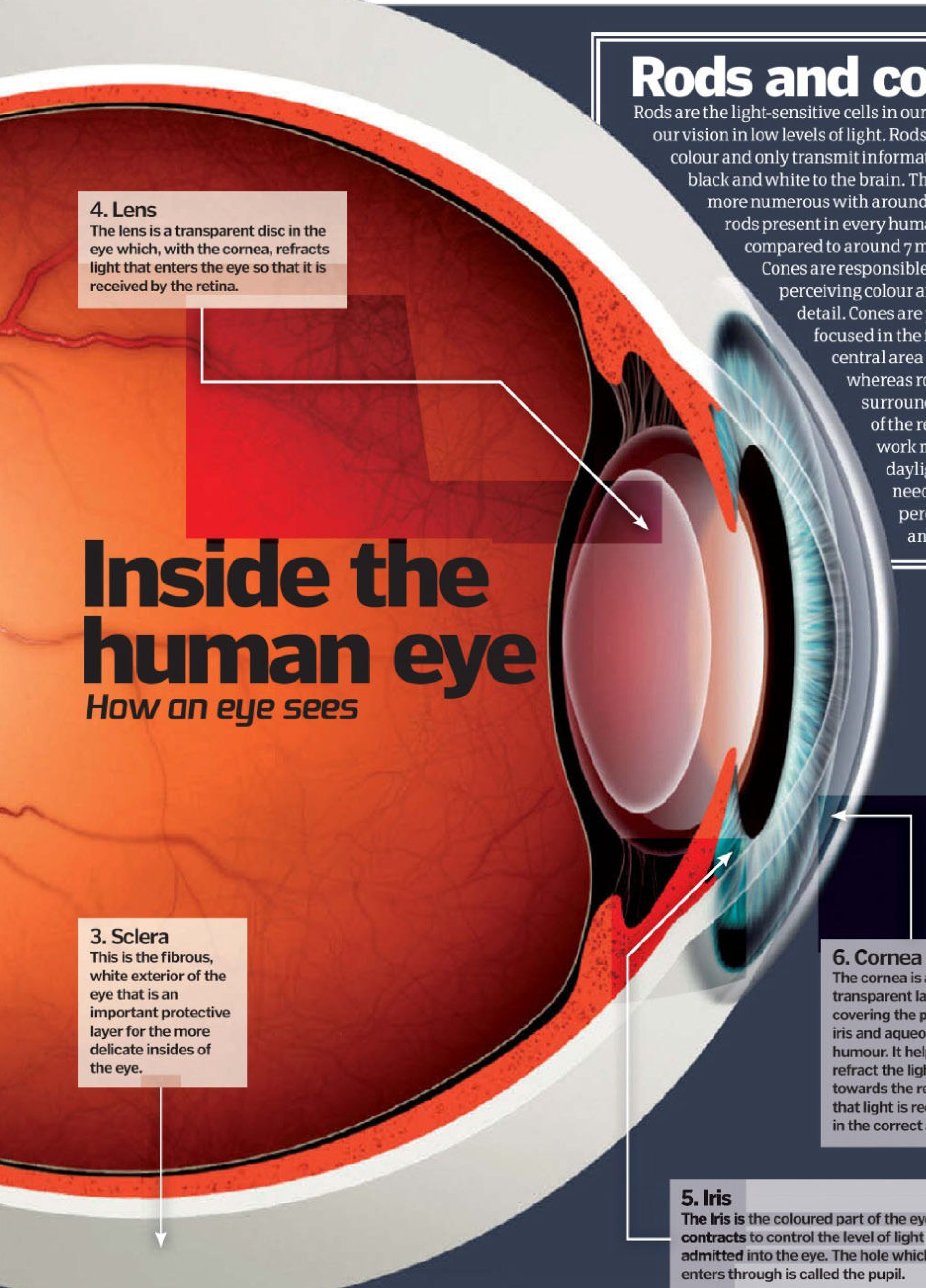
Over half the brain is involved in seeing

5 The eye uses 65 per cent of the nerve pathways to the human brain. We are very much visually dependent beings!

DID YOU KNOW? The study of the iris of the eye is called iridology

Inside the human eye

How an eye sees



4. Lens
The lens is a transparent disc in the eye which, with the cornea, refracts light that enters the eye so that it is received by the retina.

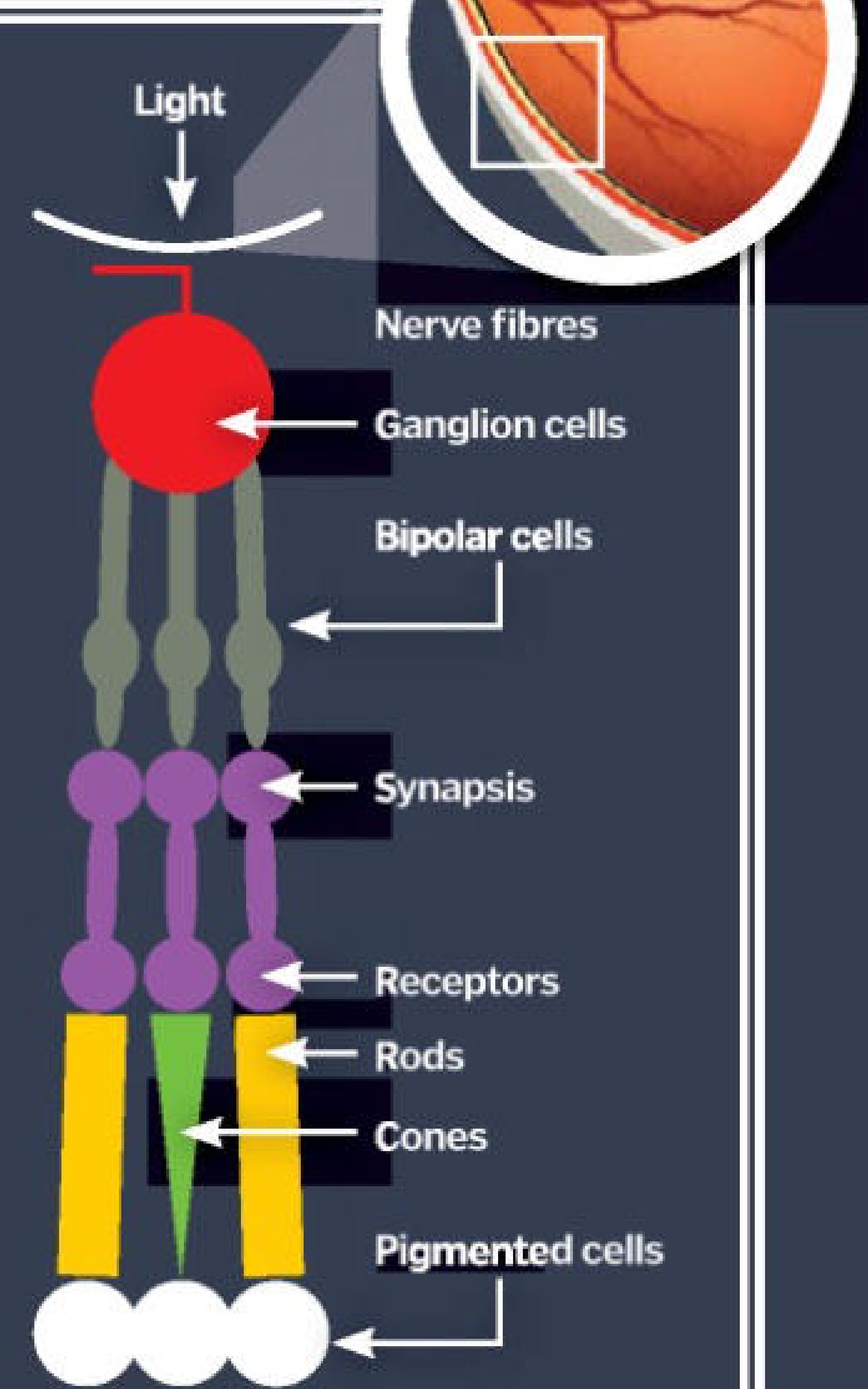
3. Sclera
This is the fibrous, white exterior of the eye that is an important protective layer for the more delicate insides of the eye.

6. Cornea
The cornea is a transparent layer, covering the pupil, iris and aqueous humour. It helps refract the light towards the retina so that light is received in the correct area.

5. Iris
The Iris is the coloured part of the eye which contracts to control the level of light admitted into the eye. The hole which light enters through is called the pupil.

Rods and cones

Rods are the light-sensitive cells in our eyes that aid our vision in low levels of light. Rods are blind to colour and only transmit information mainly in black and white to the brain. They are far more numerous with around 120 million rods present in every human eye compared to around 7 million cones. Cones are responsible for perceiving colour and specific detail. Cones are primarily focused in the fovea, the central area of the macula whereas rods mainly surround the outside of the retina. Cones work much better in daylight as light is needed to perceive colour and detail.



How do we see in colour?

Colour is not actually inherent in any object. We only see colour because objects absorb some colour from light, and reflect others. It is the reflected ones that we see and that give an object a set 'colour'. Therefore, for example, grass is not green, it purely absorbs all other colours in light and reflects back green. If an object reflects all colours we will see it as white, if it absorbs all colours we see it as black. We use cones to perceive colour as rods are blind to colour.

called rhodopsin, also known as purple visual, and the impulses are then transmitted through the optic nerve to the brain where they are perceived as 'vision'. The eye moves to allow a range of vision of approximately 180 degrees and to do this it has four primary muscles which control the movement of the eyeball. These allow the eye to move up and down and across, while restricting movement so that the eye does not rotate back into the socket.

> "The pupil can vary in size between 2mm and 8mm, increasing to allow up to 30 times more light in than the minimum"

"The scientific principle might lack wow factor, it does enable fantastic feats of engineering"

How do boats stay afloat?

Displacement enables huge ships to float on the water

At first displacement appears to be far from fascinating. Simply put, the volume of an object, when submerged in water, pushes aside the same volume of water. This simple process allows anyone to measure the precise volume of any object by then measuring the amount of fluid that either spills out of the top of the container or rises by said amount in a measuring cylinder. All very science text-book.

It becomes a little more interesting when you consider that it's this effect that enables enormous supertankers weighing up to 400,000 tons to float. It's due to the shape. As we've said, an object will float when the weight of the water it displaces is equal to the weight of the object. With the right shape, an object will displace its own weight of water before it reaches the point where it submerges. When the supertanker is launched into the sea it will sink until the water it displaces is equal to the weight of the ship itself. It will continue to sink deeper and deeper, displacing more water as it's loaded up with oil. If a ship was loaded with enough cargo the total weight of the ship and load would exceed that of water being displaced and it would sink.

So while the scientific principle might lack wow factor, it does enable fantastic feats of engineering like the TI class supertankers, the largest ocean going-ships in the world. They're an incredible 379 metres long, 68 metres wide and have a deadweight of some 441,585 metric tons and float thanks to the law of displacement discovered by Archimedes in the original Eureka moment.

Unladen
The ship sinks until the water it displaces equals its own weight

Fully loaded
It will continue to displace more and more water as it's loaded with cargo

Fish gills – a gas exchange story

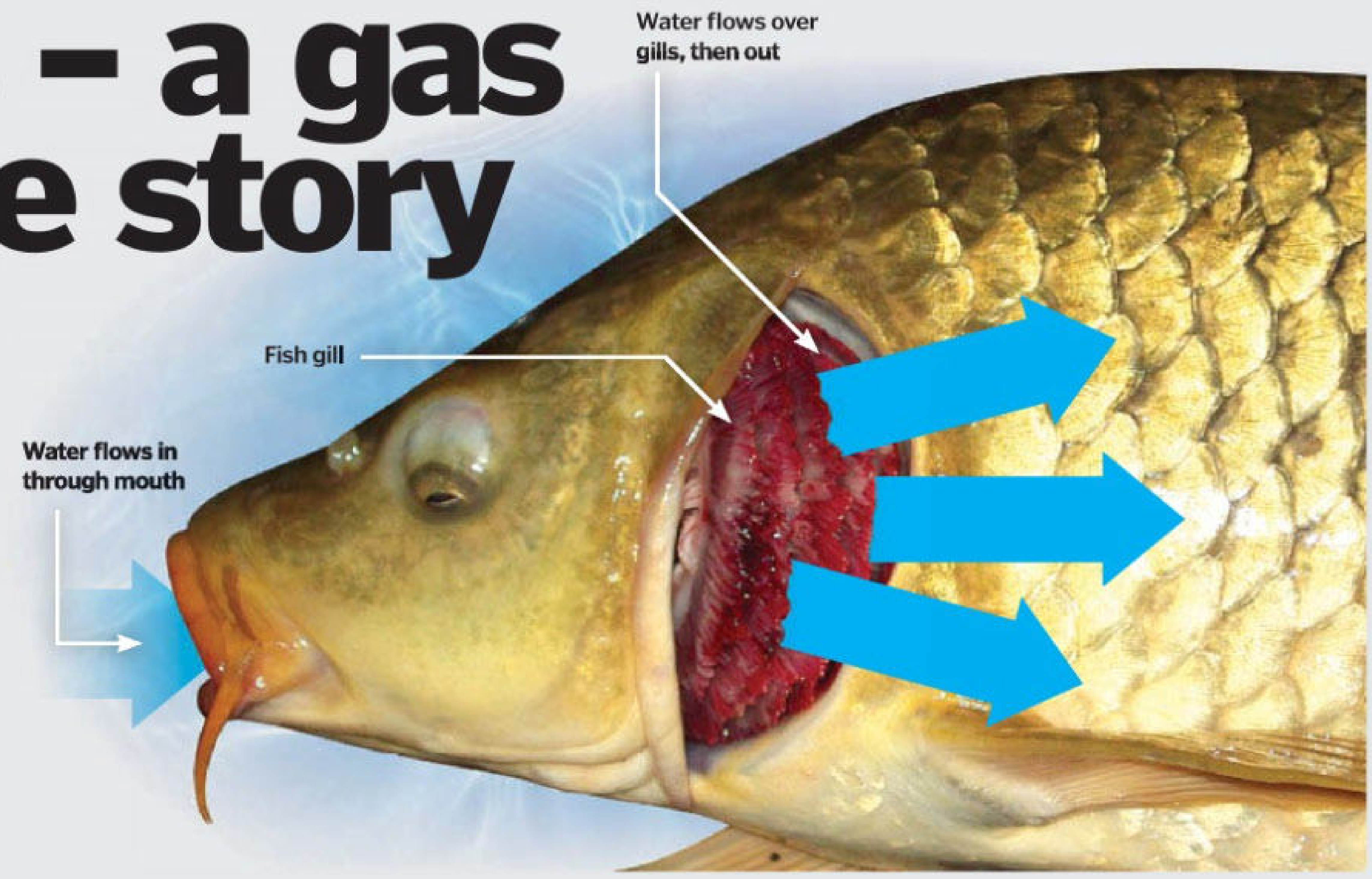
No, fish don't 'breath' water. It's much cooler than that

The process of absorbing oxygen and the release of carbon dioxide is called 'gas exchange'. Fish need oxygen in the same way humans do, they just go about getting it in a different way.

A fish has gills behind its mouth, on the side of the head (unless you're a bottom dweller like a stingray, then your gills are on the top of your head). Each gill begins with a gill arch which then splits into two filaments, much like a wishbone. Those filaments are lined with lamellae, which are little discs that are filled with capillaries. Those capillaries have oxygenated blood running through them, which is why the inside of gills are red. The more active a fish is, the more oxygen it needs, and the more lamellae it has.

As a fish swims, water moves into the mouth and flows through the gills. When a fish is still, it can still push water through the gills by opening and closing its mouth. When water passes over the lamellae, the oxygen in the water diffuses into the capillaries, oxygenating the blood. Fish have a 'countercurrent system of flow', which means that the blood flows in the opposite direction of the water. They need this clever little trick because the diffusion only works if there is less oxygen in the blood than there is in the water. So, the blood with the least amount of oxygen is meeting the 'oxygen depleted' water first, taking what's left, and then moving on to fresher, more oxygenated water.

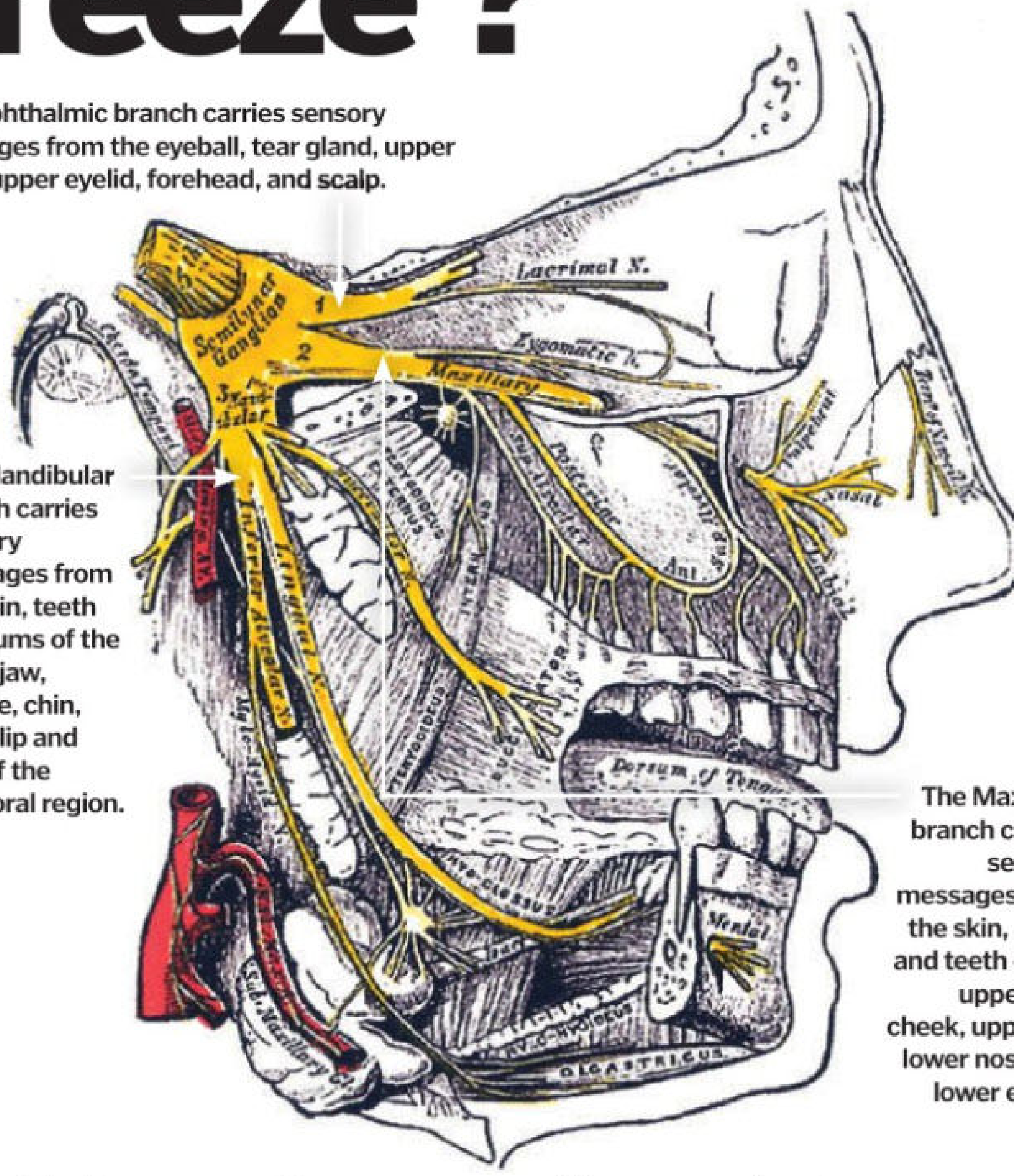
Like humans, fish must get rid of the carbon dioxide created by absorbing and using oxygen. Gills are multi-taskers – they diffuse the carbon dioxide out of the body and into the water. Fish are then free to focus on swimming.



"When a fish is still, it can still push water through the gills by opening and closing its mouth"

What is 'brain freeze'?

The Ophthalmic branch carries sensory messages from the eyeball, tear gland, upper nose, upper eyelid, forehead, and scalp.



The Mandibular branch carries sensory messages from the skin, teeth and gums of the lower jaw, tongue, chin, lower lip and skin of the temporal region.

The Maxillary branch carries sensory messages from the skin, gums and teeth of the upper jaw, cheek, upper lip, lower nose and lower eyelid.

That intense pain you sometimes get when you eat ice cream too fast is technically called sphenopalatine ganglioneuralgia, and it's related to migraine headaches

The pain of a brain freeze, also know as an ice cream headache, comes from your body's natural reaction to cold. When your body senses cold, it wants to conserve heat. One of the steps it takes to accomplish this is constricting the blood vessels near your skin. With less blood flowing near your skin, less heat is carried away from your core, keeping you warm.

The same thing happens when something really cold hits the back of your mouth. The blood vessels in your palate constrict rapidly. When the cold goes away (because you swallowed the ice cream or cold beverage), they rapidly dilate back to their normal state.

This is harmless, but a major facial nerve called the trigeminal lies close to your palate and this nerve interprets the constriction/dilation process as pain. The location of the trigeminal nerve can cause the pain to seem like its coming from your forehead. Doctors believe this same misinterpretation of blood vessel constriction/dilation is the cause of the intense pain of a migraine headache.

Blast-off!
Thermite can cut through steel as if it were paper

Thermite:
Not a bang, but not a whimper either

The movie Alien's menacing creature proves itself to be virtually indestructible due to its acid blood, which can eat through whatever it touches, including steel. Thermite is chemistry's answer to movie magic

Thermite is what you get when you combine and ignite a metal powder and a metal oxide (usually iron oxide as the oxidiser and aluminium as the fuel). This causes an aluminothermic reaction wherein the iron oxide is stripped of its oxygen, making it molten iron metal. The exothermic reaction (a reaction that releases energy in the form of heat) is not explosive – it basically looks a big sparkler. The iron is three times hotter than molten lava – it can reach 2,750°C – and can penetrate several layers of steel as if it were paper. The UV light it emits is so powerful you have to have eye protection (like a welder's mask) to look directly at it. The reaction is self-oxidising, which means you can't put it out with water. In other words, it is one nasty customer (but really cool to watch from a safe distance).

The thermite reaction is also known as the 'Goldschmidt process', named after Hans Goldschmidt, who discovered it in the late 1800s. Thermite is primarily used for welding, particularly in the railway industry. You need something pretty powerful to join railway ties and tracks, and thermite can get the job done. It's also used in demolition, and in certain kinds of grenades and bombs. Thermite hand grenades are often used in combat as a way to disable artillery and vehicles. These grenades are ideal for a quick and relatively quiet mission. If your tank's transmission has been eaten away by thermite, you aren't going anywhere in it.

In 2008, the television show *Mythbusters* tried to cut an SUV in half with thermite. They ignited a thousand pounds of thermite in the hopes of slicing it down middle from the front to back. It didn't work, but it did completely gut and ruin the car. So, needless to say, don't try it at home.

Understanding how x-rays work

With a small dose of x-ray energy, your doctor can examine your bones or circulatory system – too high of a dose and you're doomed to a painful death from cancer

An x-ray is a form of energy within a certain range of wavelengths. Any radiation between 3 × 1016 Hz to 3 × 1019 Hz (30 petahertz to 30 exahertz) is considered x-ray radiation. These are very short wavelengths, just below the ultraviolet region of the spectrum. The actual wavelength is about 10,000 times smaller than the wavelength of visible light. Short wavelength rays have high energy, which is why x-rays pass through most things. The high energy level of an x-ray photon doesn't 'fit' with others atoms' electron orbits, making it difficult for atoms to absorb x-rays unless the atom is large enough to accommodate the x-ray photon's energy.

The x-ray machine at your doctor's office generates x-rays by cranking a bunch of electrons up to a very high speed using a highly charged cathode. These electrons are then drawn to an anode made of tungsten. There, the electrons strike tungsten atoms and are either deflected or knock other electrons out of orbit. The collisions emit photons at the wavelength of x-rays which are channelled using a small window and lots of lead shielding.

From there, the rays are passed through some portion of your anatomy. Many of the them go right through, but your bones are made from larger atoms (calcium, mostly) than your other bits, and these atoms have a greater chance of absorbing some x-rays. On the other side of you, the rays strike a photosensitive plate. The more x-rays that strike the plate, the darker that portion of the plate. That's why the resulting image is a negative, with your bones the brightest: they absorbed the most x-rays. Doctors can x-ray image your blood vessels or other soft tissue by injecting or making you drink a special contrast dye that absorbs x-rays.

The x-rays that are absorbed by your body aren't entirely harmless. The x-ray photons can knock electrons away from their atoms, creating ions and starting a minor chain reaction. Ricocheting ions alter substances in your body at the atomic level, destroying or altering the DNA of your cells. This 'ionising radiation' is what did the damage suffered by those who endured unshielded, very long or frequent x-ray exposures in the days before the dangers of x-rays were understood. Today's medical x-rays are very safe when used properly, and vastly superior to being cut open every time a doctor needed a look inside you.

Images © Science Museum

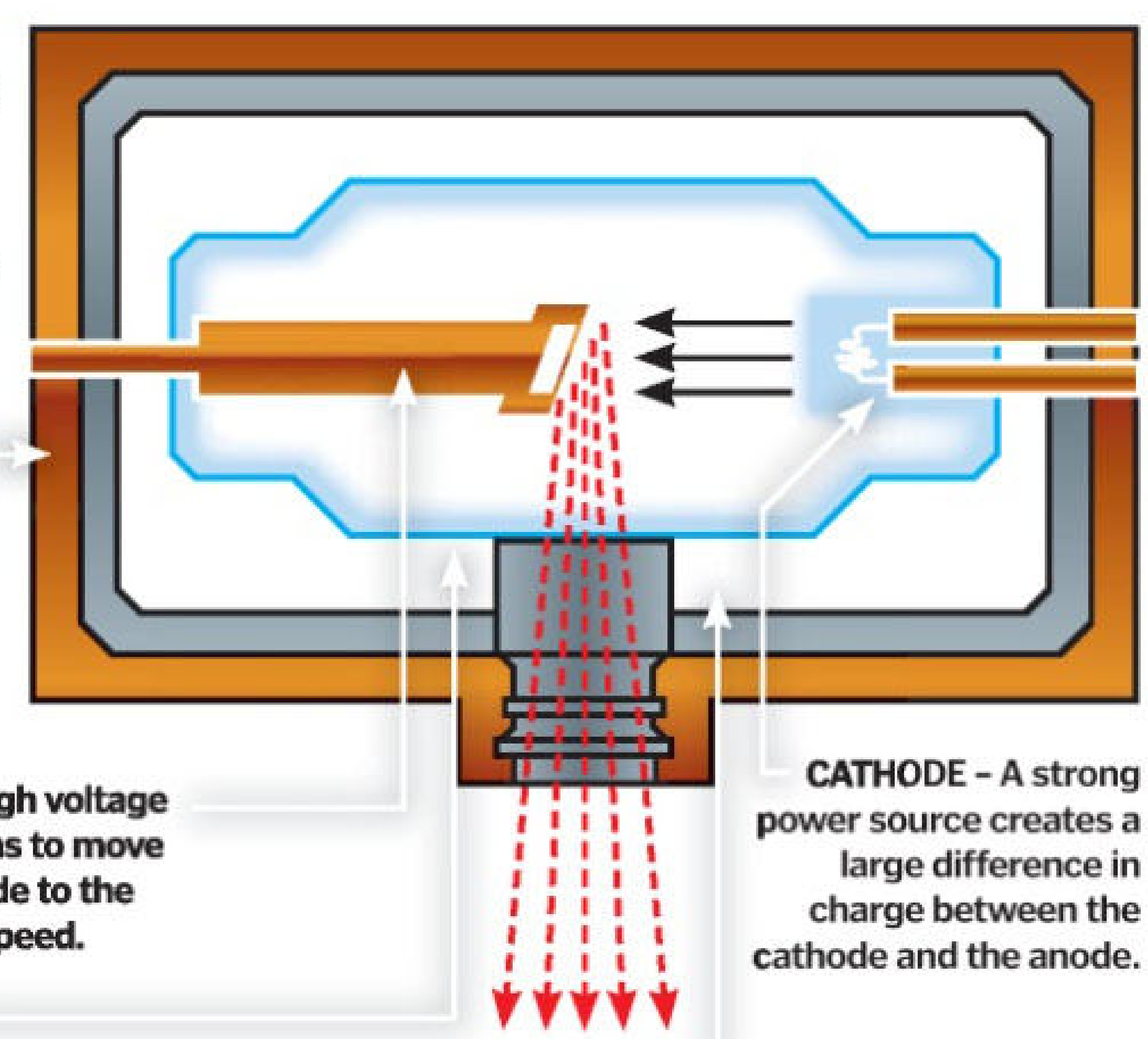
She's electric
Now we understand how Amy Winehouse gets her unique look…

Static electricity – mystery solved

Static electricity is all about freewheeling subatomic particles

Atoms are bundles of neutrons and positively charged protons – the nucleus – orbited by negatively charged electrons. When an atom has more protons than electrons, it has a positive charge. Excess electrons give an atom a negative charge. Particles and atoms with opposite charges are attracted to each other, and particles with the same charge repel each other.

When you rub a balloon against your hair, electrons from the hair atoms jump across to the balloon atoms, giving the balloon a stationary negative charge, or 'static electricity'. If you put the balloon against a wall, the negatively charged balloon atoms repel the negatively charged electrons from the wall atoms. As a result, atoms along the wall surface end up with a positive charge that attracts the negatively charged balloon atoms. The balloon then 'sticks' to the wall until the electrons redistribute themselves, giving the balloon a neutral charge.



SHIELDING – The lead casing keeps the x-rays from scattering in every direction. The rays can only leave through the window.

ANODE – The high voltage causes electrons to move from the cathode to the anode at high speed.

CATHODE – A strong power source creates a large difference in charge between the cathode and the anode.

GLASS TUBE – The entire cathode/anode apparatus is held in a vacuum tube to keep out unwanted atoms.

COOLANT – A coolant oil is circulated around heat sinks attached to the cathode and anode. X-ray machines are inefficient and generates large amounts of waste heat.

Heart lube
1 Your heart is surrounded by a membrane called the pericardium. It secretes fluid which acts as a lubricant so the heart doesn't suffer wear and tear when it beats.

Tubes of air
2 Artery literally means 'wind pipe'. Anatomists dissected corpses to learn about the body. After death, blood drains from arteries, so they were full of air, hence the name.

Coronary bypass
3 A coronary bypass is a surgery in which surgeons shunt a coronary artery around a blockage using blood vessels from other parts of the body.

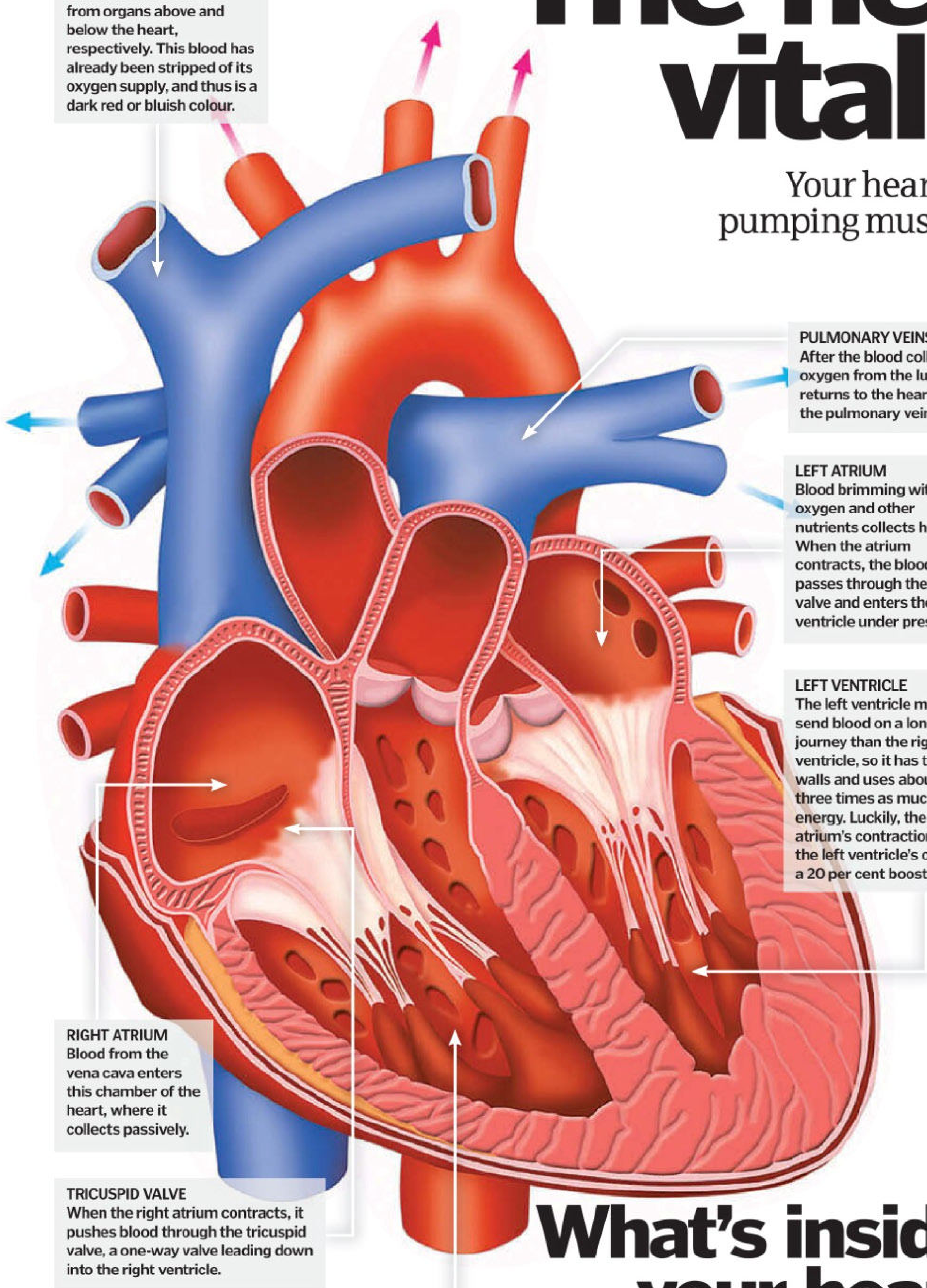
Veins vs arteries
4 The ultimate difference between veins and arteries lies in whether they actually carry blood toward (veins) or away (arteries) from the heart.

Heart power
5 Your heart runs on just a few watts of power, about the same as a small LED light. Over the course of a long lifetime, it adds up to several billion joules.

DID YOU KNOW? *The heart pumps about 1 million barrels of blood during the average lifetime*

The heart – a vital organ

Your heart is a turbocharged double-pumping muscle that beats more than 40 million times every year



What's inside your heart

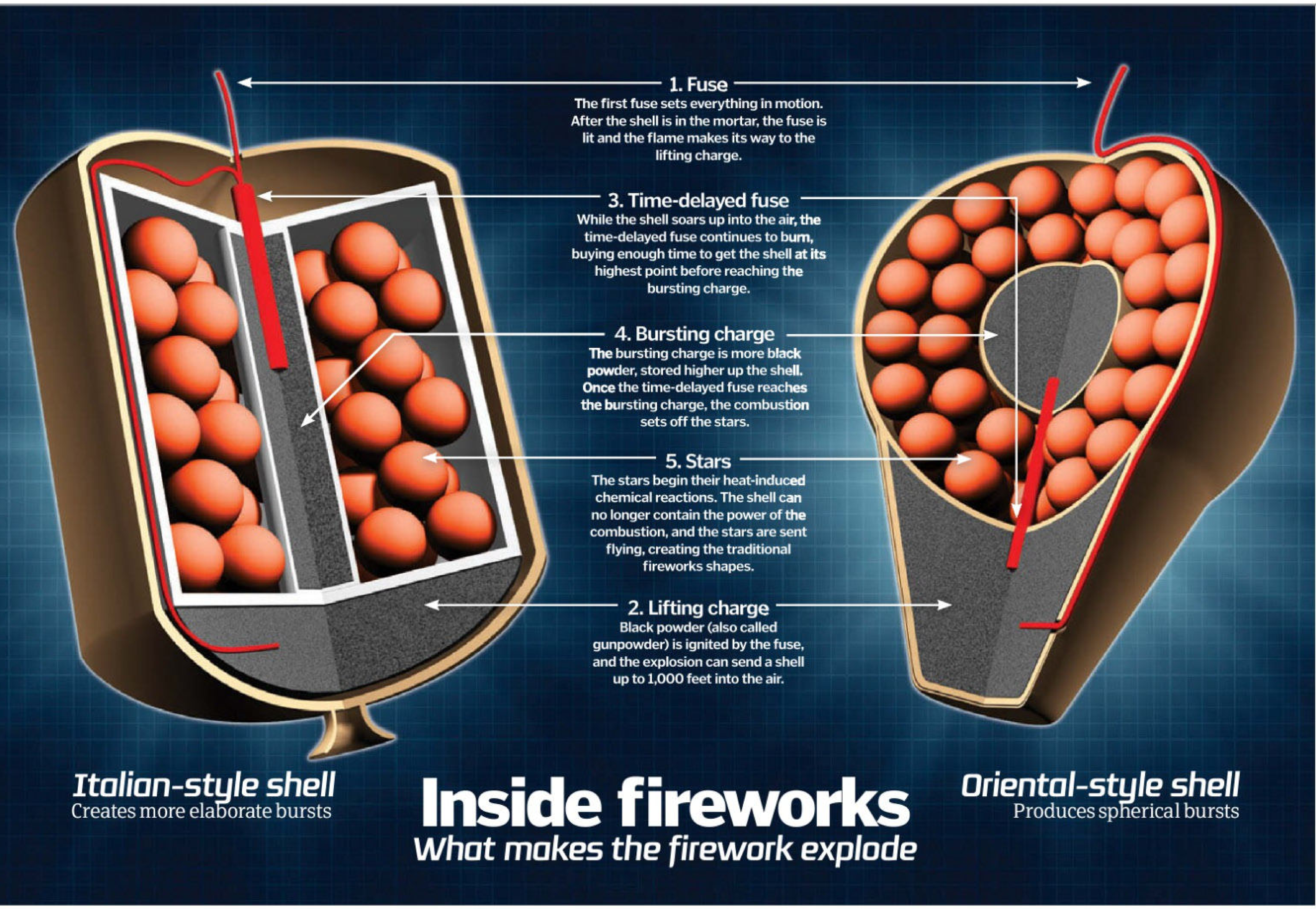
Find out how your heart pumps blood around your body

Not only does your heart do amazing things, it does so tirelessly, every minute of every day from the moment you're born (actually, even a bit before then) to the instant that you die. It weighs somewhere between eight and 12 ounces – slightly more if you're male, less if you're female. Its sole purpose is to push blood through your circulatory system, providing crucial oxygen and other nutrients to all your organs.

The heart is considered a double pump because the right half sends 'used' blood to your lungs. There, the blood drops off a load of carbon dioxide and picks up some fresh oxygen, which you have helpfully provided by breathing. Then the oxygenated blood returns to the left half of the heart. This 'heart-to-lungs-to-heart-again' trip is known as pulmonary circulation. The left side of the heart then pumps this oxygenated blood to every organ in your body other than your lungs. Your brain, your skin, the muscles in your thigh, your spleen – they all get blood (and therefore oxygen) by virtue of your beating heart.

Even the heart itself gets blood, via a special set of veins and arteries known as the coronary system. The myocardial muscle within the wall of the heart needs oxygen and other nutrients to keep beating. Unfortunately, the coronary arteries that do this job are very narrow, between 1.7 and 2.2 millimetres in diameter. If they become clogged with cholesterol or other fatty deposits, the heart stops working. This is bad for you.

Of course, the relatively simple concept of the double pump is fairly complex in practice. A series of valves control blood flow to the heart's four chambers, allow for the build-up of enough blood pressure to get the job done, and direct the blood to the correct veins and arteries.



How fireworks explode

These bright and festive chemistry experiments have been delighting people for hundreds of years

Despite all their different colours, shapes, and sounds, all fireworks have the same basic components. Aerial fireworks consist of a shell made of heavy paper that holds the 'lift charge', the 'bursting charge', and the 'stars'. All of these glittery spectacles come from good old-fashioned combustion. Combustion is a chemical reaction between two substances (a fuel and an oxidant) that produces light and heat. The heat causes gasses to expand rapidly, building pressure. The shells are tightly wrapped cylinders, which provide good resistance to this pressure, giving it a short time to build in intensity. Then, when the reaction overpowers the shell, you get the explosive firework effect.

It all starts when the shell is placed into a mortar (a cylinder the same size as the shell, which holds the firework in place while the fuse burns). The lift charge, at the bottom of the shell, is basically concentrated black powder (charcoal, sulphur, and potassium nitrate). When lit by the dangling fuse, the lift charge sends the shell into the air. Basic firecrackers are just paper-covered black powder: you light the fuse and listen to the popping sound.

The bursting charge is another round of black powder with its own time-delayed fuse higher up in

5 TOP FACTS FIREWORKS

World's largest display
1 Was set on 31 December 2006 in Funchal, Madeira, as part of Portugal's new year celebrations. 66,236 fireworks lit up the sky to claim the world record.

Most rockets in 30s
2 The world record for the most rockets fired in 30 seconds is 56,405, achieved on 16 August 2006. An attempt to beat this on Bournemouth seafront in 2009 failed.

Tallest bonfire
3 Hiroshima, Japan was the setting for the world's tallest bonfire – a quite collosal 123ft high, lit on 9 February 2003 as part of the city's Centennial celebrations.

Gunpowder plot
4 Bonfire Night held on 5 November is the celebration of the failed 1605 gunpowder plot in which Guy Fawkes attempted to blow up the British Houses of Parliament.

Huge Catherine wheel
5 We have the Newick Bonfire Society to thank for the monsterous 85-foot world-record-breaking Catherine wheel constructed in the UK on 30 October 1999.

DID YOU KNOW? A modern sparkler burns at a temperature over 15 times the boiling point of water

What makes the colours?

Colours are a matter of delicate balance. The wrong combination can mean a wrong colour, or worse

Colours involve different measurements and combinations of oxygen producers, fuels, binders, and colour producers. You can make colour through incandescence – light created through heat (orange, red, white), or luminescence – light created from a chemical reaction without extreme heat (blue, green). It's all about temperature control and balance.

- Red – Strontium and lithium
- Orange – Calcium
- Gold – Incandescence of iron, charcoal or lampblack
- Yellow – Sodium
- Electric white – Magnesium or aluminium
- Green – Barium plus a chlorine producer
- Blue – Copper plus a chlorine producer
- Purple – Strontium plus copper
- Silver – Aluminium, titanium or magnesium powder or flakes

The short life of a firework

A lot of careful planning has to go into a multi-break firework. All for about three seconds' worth of entertainment…

the shell. The bursting charge creates the heat to activate the stars that surround it and explode them outward from the shell. The stars are where the magic happens.

Stars are balls made up of fuels, oxidisers, colour-creating combinations of different kinds of metals, and a binder to hold everything together. The stars can be arranged within the firework shell to create shapes. The shapes can be things like hearts, stars, and circles. Hundreds of stars can be used in a single firework shell.

More complex fireworks – for example, ones that produce a shape like a smiley face, have multiple phases of different colours, or make extra sounds like whistles – have shells with a more intricate infrastructure. In these types of fireworks, there are more time-delayed fuses linked to various bursting charges with their own surrounding stars. Each of these may sit in its own individual interior shell. These are called 'multi-break shells'.

While a sight to behold, fireworks are individually wrapped chemistry experiments. Tapping one too hard or creating a static electricity shock with your synthetic-material clothing could be deadly and one exploding near to your face could result in horrific burns and even blindness. They don't have the word 'fire' in them for nothing.

Why do we get drunk?

It's the drug of choice for many, but just how does alcohol get you drunk, and why do we suffer from the side effects?

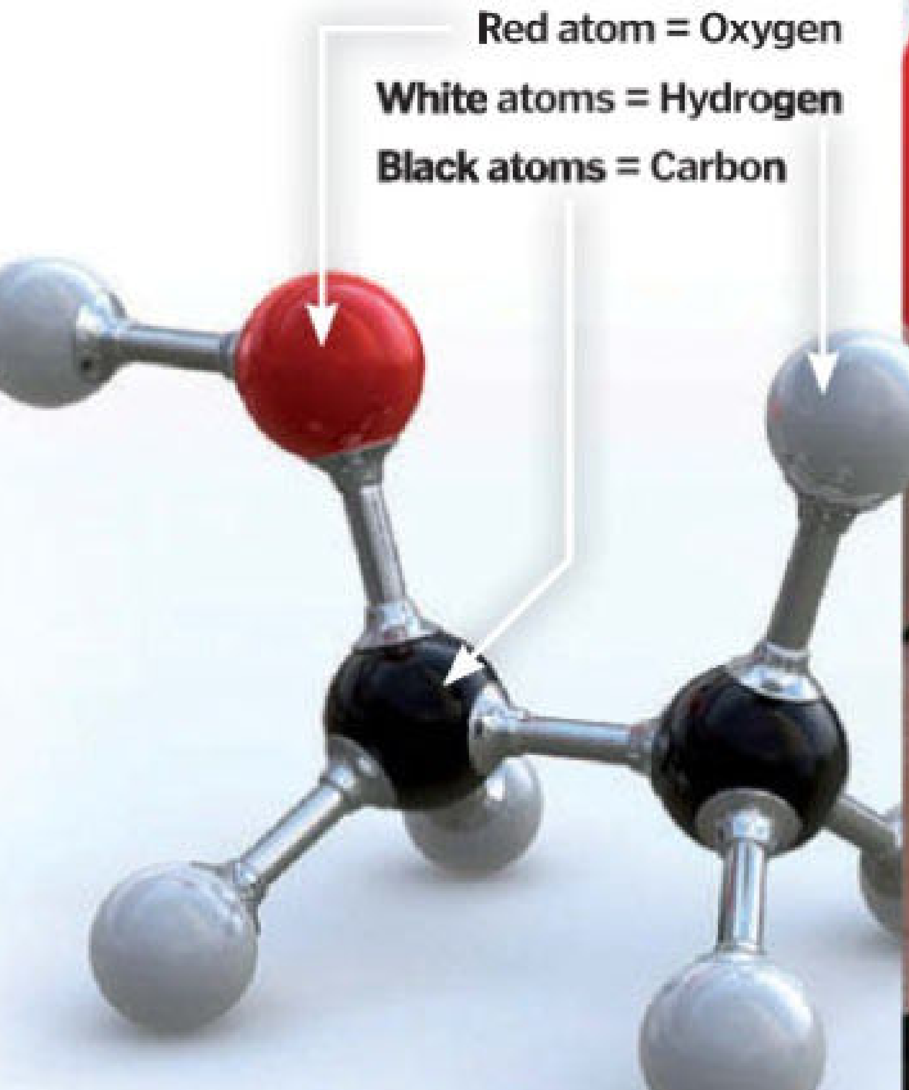
There are actually many kinds of alcohol in the chemical world, but the one we drink the most is ethanol. It's the particular shape of an ethanol molecule that gives a glass of beer or a shot of the hard stuff its specific effects on the human brain. The molecule is very tiny, made up of just two carbon atoms, six hydrogen atoms, and one oxygen atom. Ethanol is water soluble, which means it enters the blood stream readily, there to be carried quickly to all parts of the body (most notably the liver and the brain). It's also fat soluble; like an all-access pass through various cell membranes and other places that are normally off limits.

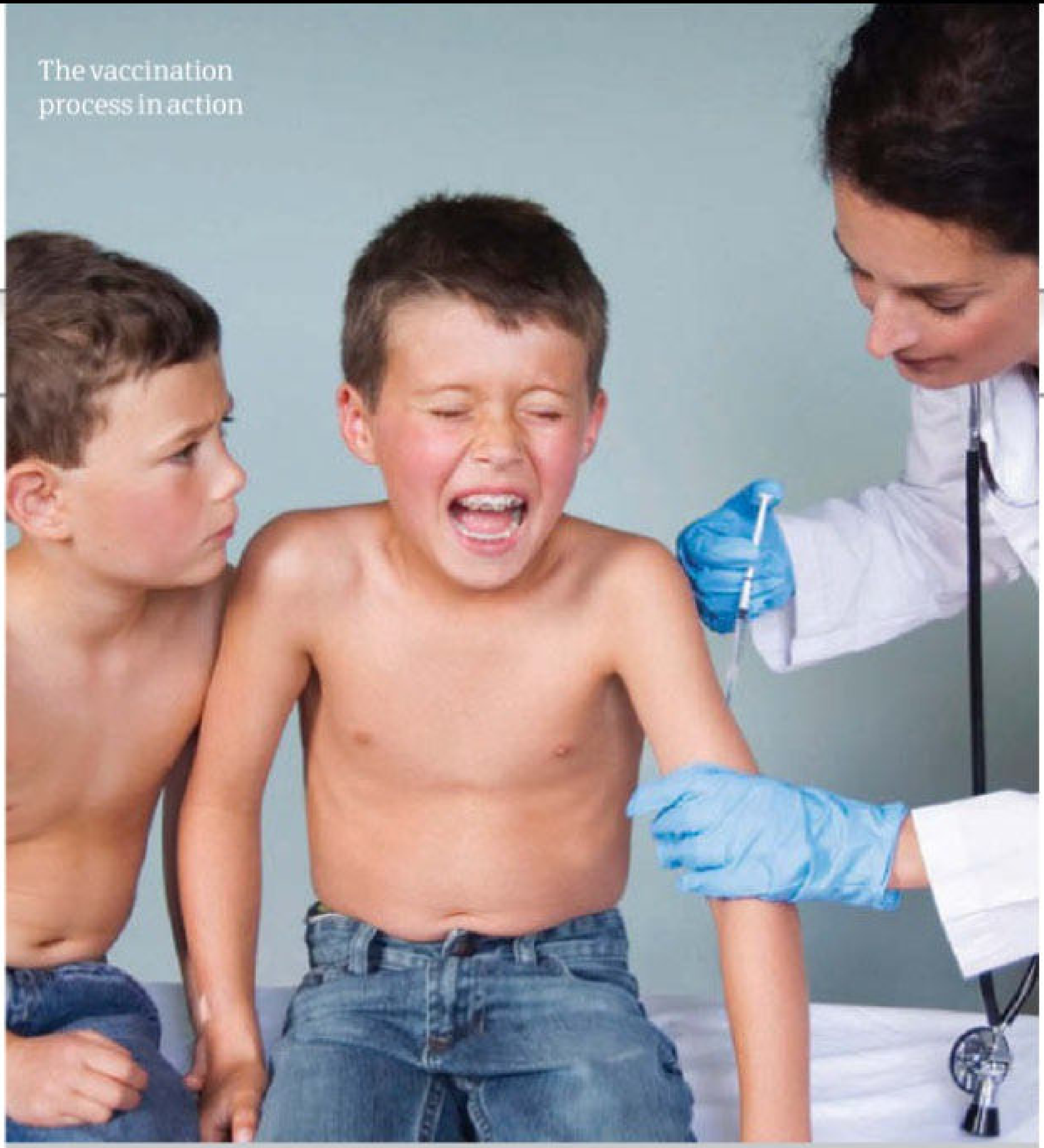
A certain portion of the ethanol you drink passes through your stomach to your small intestine, is absorbed into your bloodstream and carried to your brain. That's what we're really concerned with. Research has not conclusively determined exactly how ethanol accomplishes all of its various effects in the brain, but there are some well-supported theories. The slow reactions, slurred speech and memory loss of a drunk are probably caused by ethanol attaching to glutamate receptors in your brain's neural circuitry. These receptors normally receive chemical signals from other parts of the brain, but instead they get an ethanol molecule. This disrupts the flow of signals and generally slows the whole brain down.

Ethanol also binds to GABA (gamma-aminobutyric acid) receptors, which normally serve to slow down brain activity. Unlike glutamate receptors, ethanol actually makes GABA receptors more receptive, causing the brain to slow down even more. But alcohol isn't simply a depressant, because it also stimulates the production of dopamine and endorphins, chemicals that produce feelings of pleasure. Research hasn't yet revealed the exact mechanism involved, but it may be similar to the way ethanol stimulates the GABA receptors.

Ethanol molecule

The particular shape of an ethanol molecule makes it ideally suited to getting humans drunk. Slight differences in the charge at each end of the molecule make it both water and fat soluble.





The vaccination process in action

Immunisation: how it keeps you healthy

Your body has the tools to keep you safe from disease

Before the vaccine, everyone got chicken pox. You'd get it once as a kid and then wouldn't get it again. This is a perfect example of immunisation.

Antigens are foreign molecules that when introduced, the body recognises as an 'intruder' and fights with antibodies, creating an immune response. Antibodies neutralise the antigen so that the next time around they know what to do. Vaccinations make immunisation even more convenient because you don't even have to get sick the first time around while your antibodies do their work.

Vaccines carry inactive bacterial toxins, killed microbes, parts of microbes, and weakened microbes. Basically, enough 'stuff' to catch your antibodies' attention, but not enough to actually make you sick. Nowadays, instead of actually having chicken pox, kids often get the vaccination, therefore avoiding the itchy bumps and fever but creating the 'immunological memory' needed to fight it the next time it tries to invade the body. Vaccinations have led to the eradication of smallpox and are coming very close to eradicating polio worldwide. Not too shabby.

> "Your immune response ensures future health"

Vaccinations and natural immune responses are called 'active immunity' because it requires the work of your immune system. 'Passive immunity' occurs when actual antibodies are transferred from one person to another. An example is when a mother breast-feeds her infant, transferring her own natural resistance to certain antigens in her baby. Passive immunity only lasts up to a few months. After that, the baby's own immune system has hopefully strengthened to be able to fight antigens on its own. Another use for passive immunity is in rabies cases. Someone bitten by a rabid animal does not have enough time to allow for an active immunity response to a vaccine, so they are given antibodies from someone who has been vaccinated to fight the virus in the interim.

Ancient wisdom
1 With its definition stretching back to the 15th Century, the word 'atom' is Greek for invisible. This is partly true.

The 117th element
2 Although ununoctium (118) is known, element 117 is actually yet to be discovered… so get looking!

The light fantastic
3 Hydrogen with no circling electron is in a plasma state and this is the main ingredient of stars.

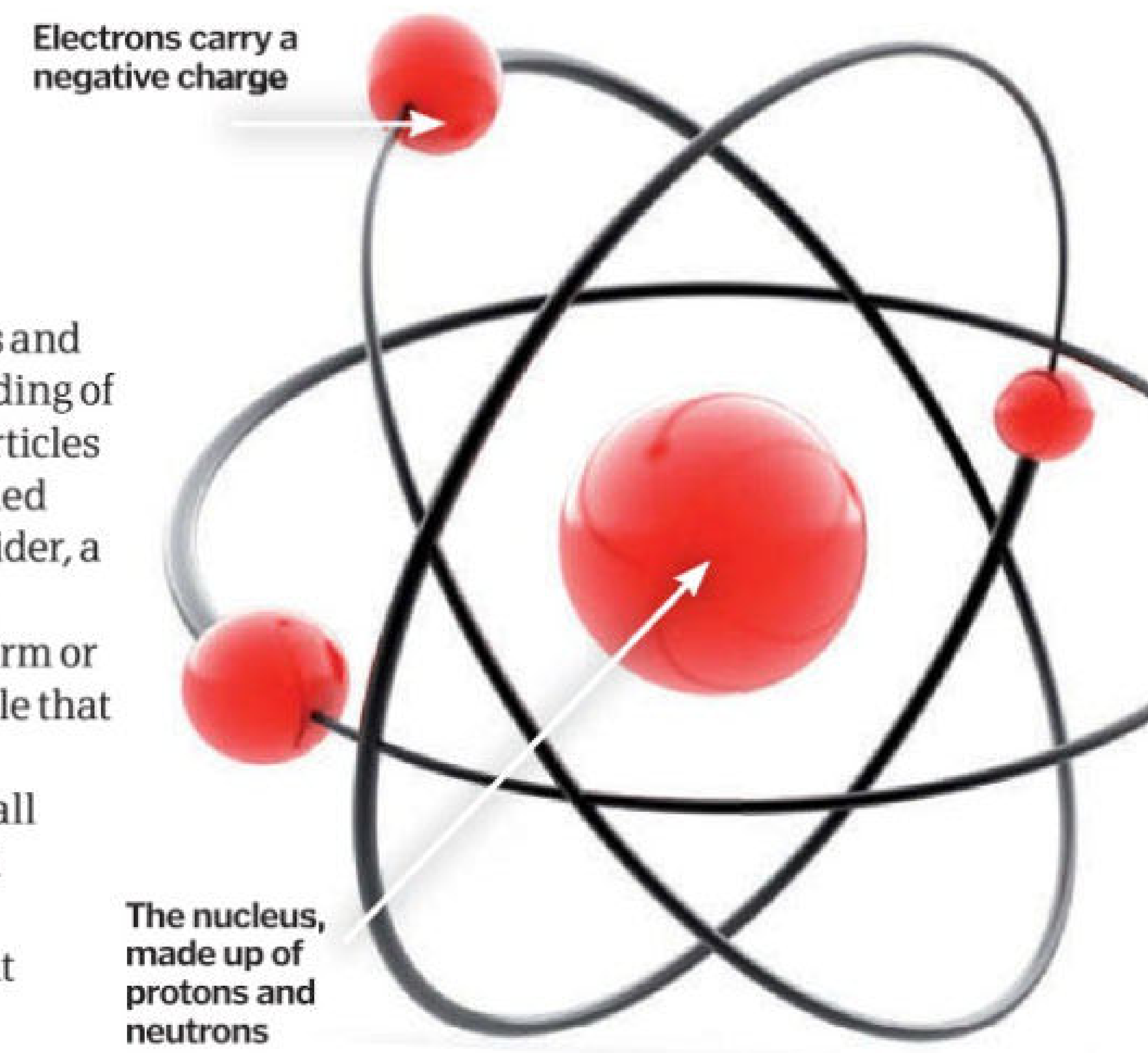
Atoms in you
4 An 80kg man would contain roughly 8,000,000,000,000,000,000,000,000,000 atoms… that's 27 zeros!

Inside out
5 Both protons and electrons exist within the central nucleus, whereas electrons are orbital.

DID YOU KNOW? *Strong electromagnetic forces bind the electrons and nucleus together*

What are atoms?

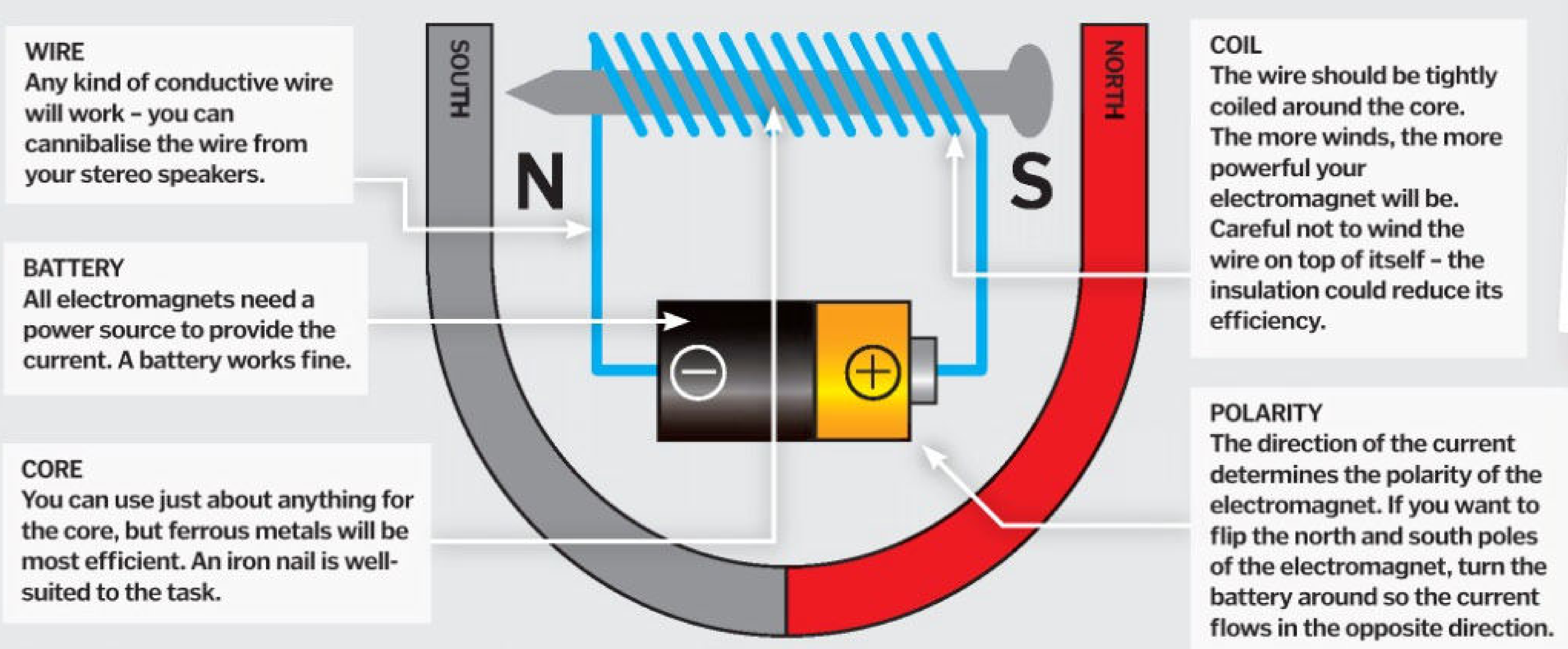
The little things in life make the biggest difference

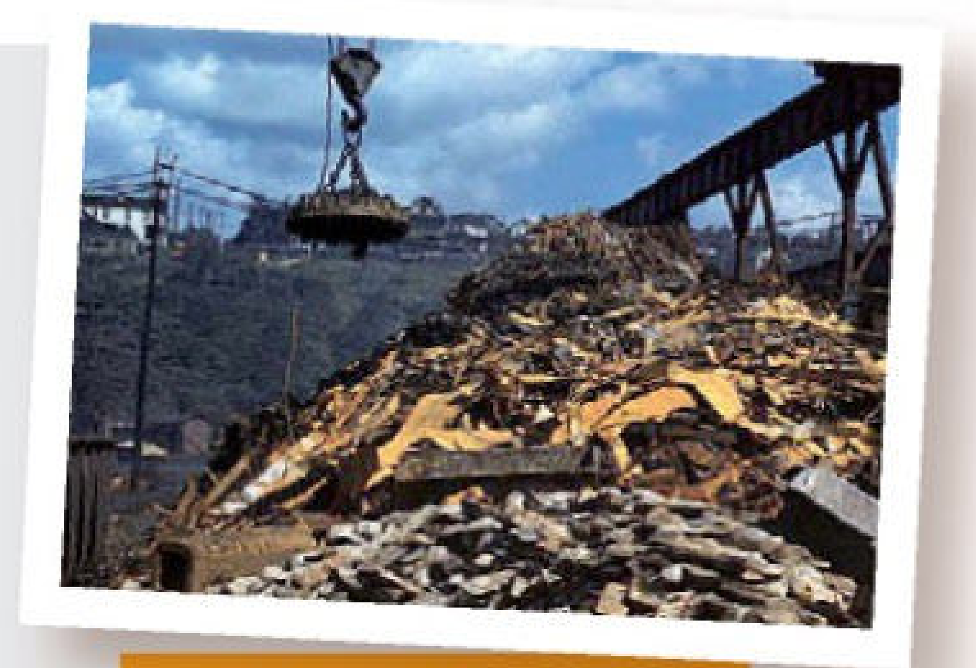


The big bang has a lot to answer for. The astonishing cosmic forces hypothesised to have created the universe formed all known types of atom. Atoms which have since gone on to do great things; creating stars, planets, us, and indeed the pen and paper used by Dmitri Mendeleev in his 1869 publication of the first universally recognised form of the periodic table; essentially a tabular list of the atomic weights of all 117 known chemical elements.

Of course, depending on the way atoms are bonded together they are the very substance of everything we see and know. Just as it's mind-boggling to contemplate the size of the universal macrocosm as we look out into the cosmos, the microcosm is equally astounding. Atoms are made up of various numbers of protons, neutrons and electrons. But just like the expanding understanding of the universe, smaller and smaller sub-atomic particles are being discovered all the time. This quest has led particle physicists to build the Large Hadron Collider, a particle accelerator with the primary purpose of smashing atoms with such force as to either confirm or rule out the existence of the Higgs boson; a particle that could explain the origin of the universe's mass.

Atoms hold the key to understanding where it all started; where we're from in the truest sense and therefore render much pre-existing philosophy redundant. Apparently, the answer to life isn't out there as we once thought, it's in here!





How electromagnets work

Just by running electrical current through a coil of wire, you can turn just about anything into an electromagnet

Electromagnets work thanks to a fundamental force called electromagnetism. In the 19th Century, Hans Christian Ørsted noticed that a wire with a current running through it affected a nearby compass. The current was creating a magnetic field. Later research showed that electric current and magnetism are actually two aspects of the same force. This force works both ways – a moving magnetic field creates electric current. This is, in fact, how generators work.

The mechanism that actually causes electromagnetic force involves quantum physics and the transfer of photons, but the mechanics of an electromagnet are quite simple. All you need is a power source, a wire and a core. When a current passes through a wire, the resulting magnetic field takes the shape of concentric circles around the circumference of the wire. The magnetic field gets weaker farther from the wire. Coiling the wire makes for a much more efficient electromagnet, because inside the coil the magnetic fields of many portions of the wire are concentrated into a small space.

The coil is wrapped around the core, which should be made of a magnetically permeable material such as iron. The core itself is not magnetic under normal circumstances, since all the magnetic areas within it (known as magnetic domains) are pointing in different directions, cancelling each other out. When the current is turned on, the magnetic field generated by the coil of wire forces the magnetic domains to line up, which makes the core itself magnetic. The stronger the current, the stronger the magnetic field. This makes even more of the domains line up, increasing the overall strength of the electromagnet.

When the current is shut off, most core materials revert to a non-magnetic state as the domains flip back to the original positions. However, certain substances can become permanent magnets and retain the alignment of the magnetic domains even in the absence of current.

5 TOP FACTS
ELECTROMAGNETS IN ACTION

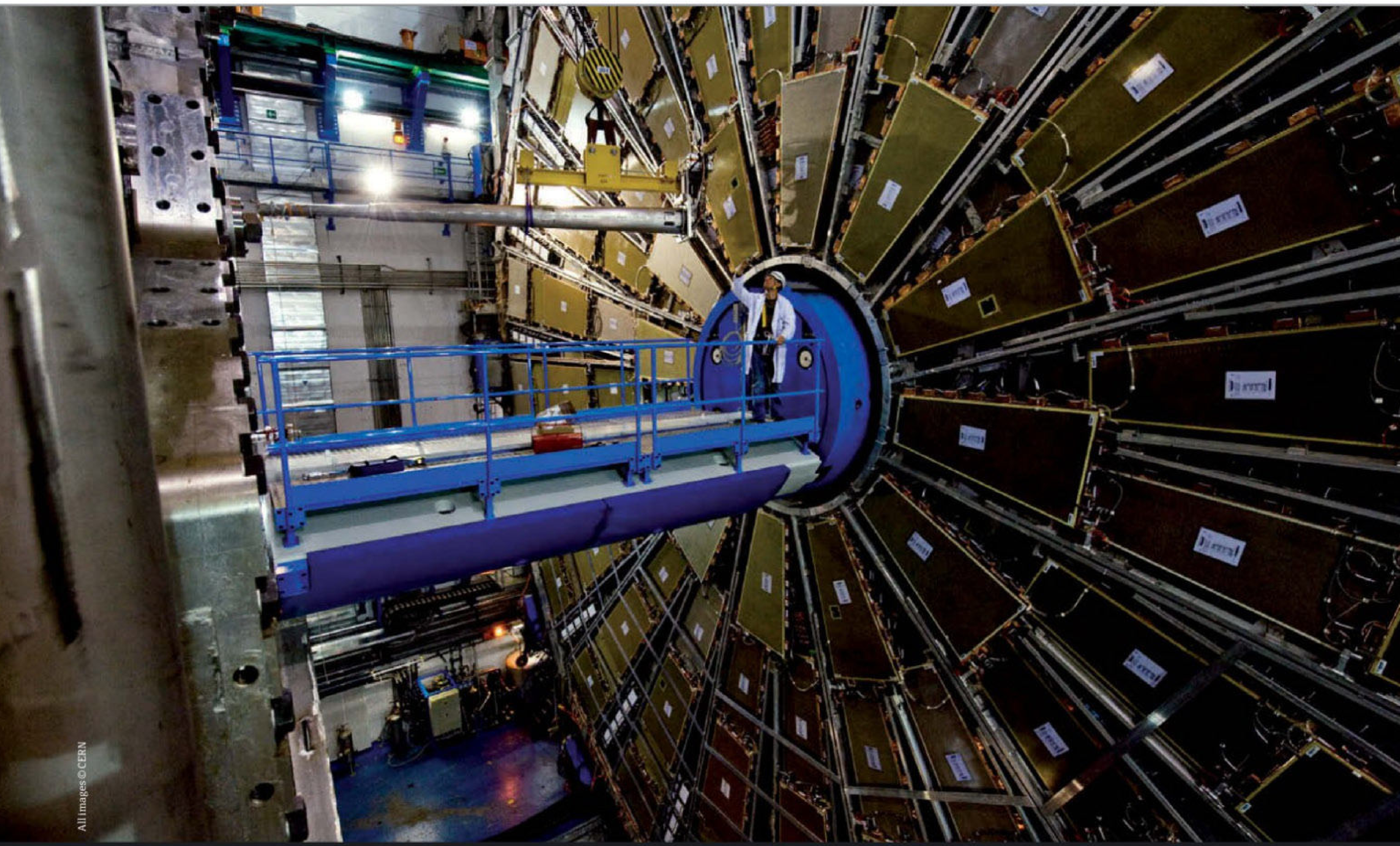
1 Scrapyard magnetic cranes
Magnetic cranes in scrapyards turn on the powerful magnet to lift tons of metal, then turn it off to drop the scrap.

2 Recycling plants
In keeping with the scrapyard theme, electromagnets are used to separate certain metals from huge piles of unsorted scrap and waste.

3 Speakers
The speakers in your stereo or guitar amplifier use electromagnets to convert electrical energy to sound waves – variations in the current make the magnets, and the speaker cones, vibrate.

4 Electric motors
Electromagnets, in combination with permanent magnets, are an integral part of electric motors, which are pretty much everywhere.

5 Particle colliders
Experimental devices such as the Large Hadron Collider use massive supercooled electromagnets to focus the particle beams.



All images © CERN

Return of the Large Hadron Collider

After nine months of repair work, the biggest machine in the world (and the most expensive science experiment of all time) is once again ready for action

Remember how much fun you used to have hurling toy cars into each other for hours on end? The Large Hadron Collider (LHC) is something like that – except the cars are subatomic particles that race along a 27-kilometre circular track buried 50-170 metres below Switzerland and France, crashing into each other at 99.9999991 per cent the speed of light. The people doing the smashing also have more noble intentions than your average six-year-old. Scientists from all over the world have high hopes that the LHC will unlock revolutionary secrets of the universe.

On 10 September 2008, CERN successfully sent a single particle beam around the LHC. But just nine days later, they had to shut it down following a major malfunction.

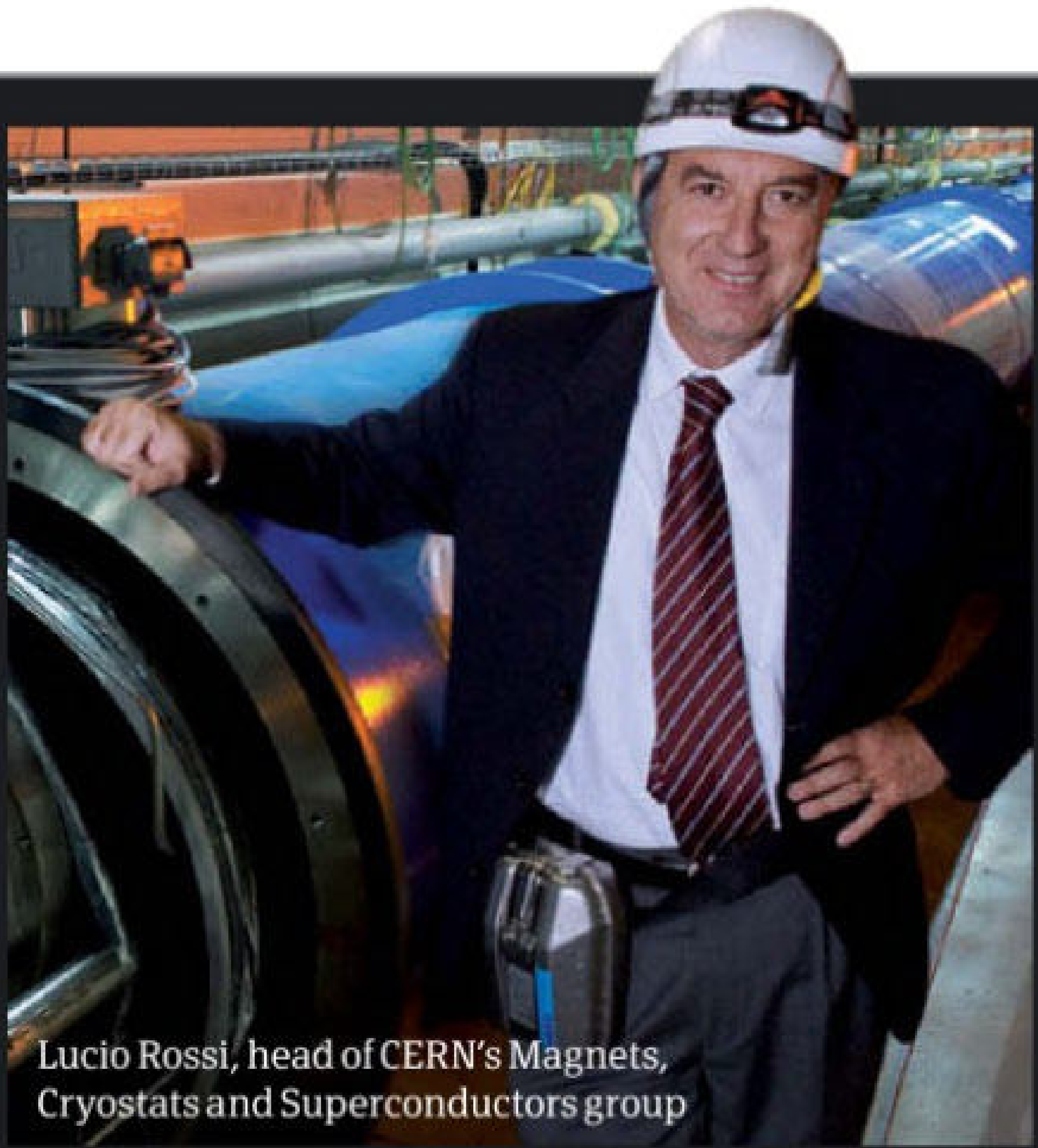
Here's the skinny on what the LHC does, how it does it, what went wrong, and what could happen after the European Organisation for Nuclear Research (CERN) fires it up again in November.

Why smash?

The basic idea of the LHC is to accelerate either streams of protons (part of an atom's nucleus) or streams of ions (charged atoms) in opposite directions, so that they collide into each other. The particles – collectively known as hadrons – are so tiny that making any two hit is extremely difficult. CERN compares this challenge to trying to launch individual needles into each other from two positions ten kilometres apart.

The LHC manages to boost the collision rate by upping the particle count and focusing a huge number of particles into a very small area. Each particle stream includes around 3,000 bunches, and each bunch contains as many as 100 billion particles. The bunches cross each other around 30 million times a second, which means the LHC can produce up to 600 million collisions per second.

As cool as smashing things together is, you can rest assured the 24 countries who funded the LHC didn't drop €3 billion just for the heck of it. They


Lucio Rossi, head of CERN's Magnets, Cryostats and Superconductors group

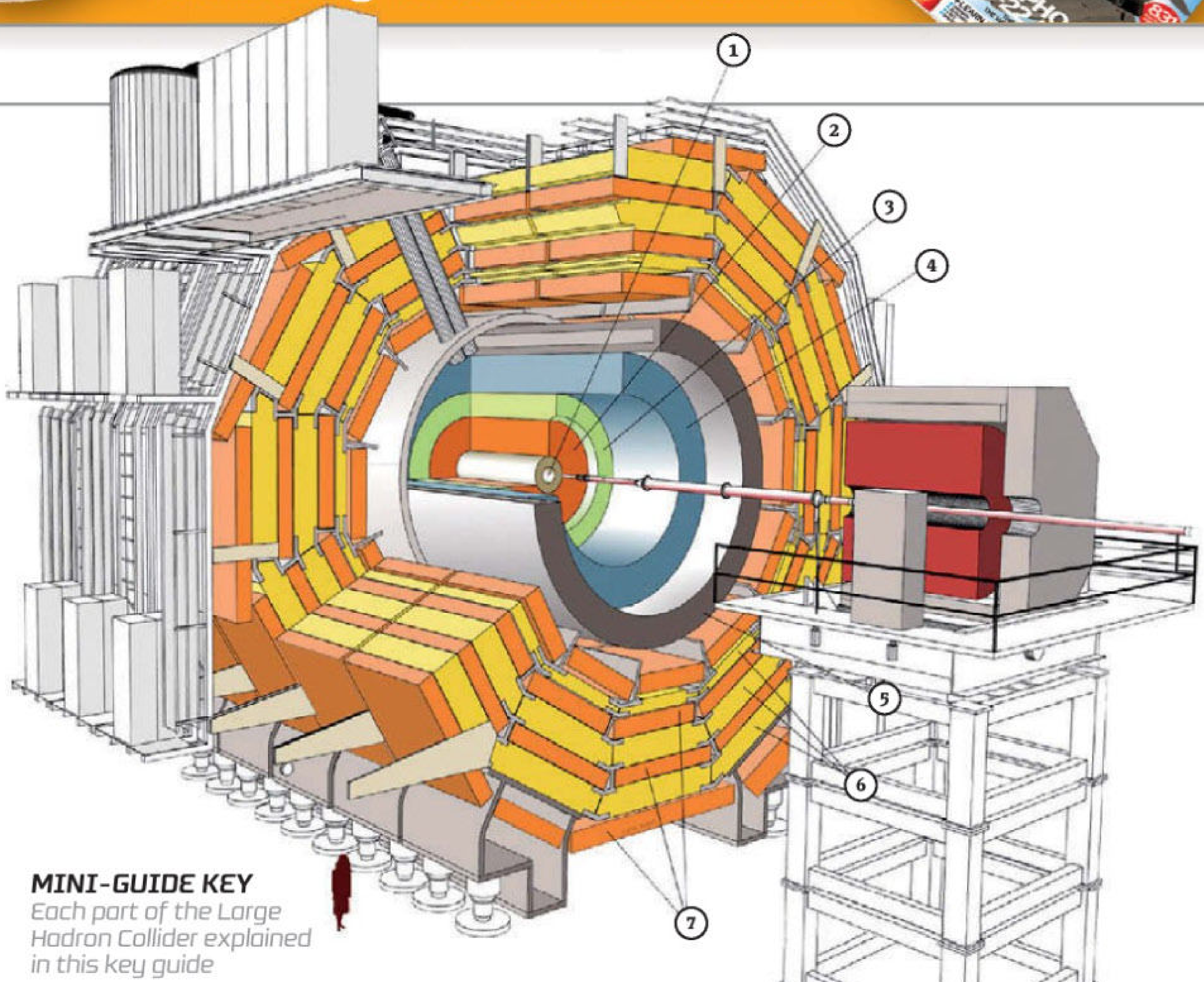
undertook the project to fill in gaps in our fundamental understanding of what makes the universe tick.

Understanding the universe is something like devising the recipe for a mysterious dish when the chef is long gone. We can never actually witness the moment of creation, so scientists have to piece together theories by examining what exists today. This means, in large part, investigating the smallest particles that make up all matter. The high intensity collisions in the LHC are powerful enough to break ions and protons into smaller secondary particles we've never observed before. A collection of sophisticated detectors will measure the position, mass, energy, charge, trajectory, and speed of the particles from each collision and record the results. Then scientists will pour over the data to figure out what sorts of particles were produced and what they did. The results could prove or disprove various theories. Or it could turn up something completely unexpected.

The big mysteries

So, what could these particles tell us? Over the years, scientists have developed a substantial body of knowledge about subatomic particles, called the Standard Model of particles and forces. But while the Standard Model explains many things well, it doesn't account for a number of known phenomena. Scientists hope LHC experiments will shed light on these perplexing mysteries:

- What causes gravity?
- What gives something mass, and why do some particles have mass while others don't?
- What are dark matter and dark energy? Scientists know it makes up 96 per cent of the universe, but since it's invisible, they don't know much about it.
- Why is there matter and no antimatter? Scientists believe that the Big Bang created equal amounts of matter and its opposite counterpart, antimatter. Matter and antimatter particles should destroy each other when they meet, yet somehow a certain amount of matter survived, while no antimatter did. Scientists want to know why nature gave matter the edge.
- What was matter like just after the Big Bang?
- Are there other dimensions?



MINI-GUIDE KEY

Each part of the Large Hadron Collider explained in this key guide

1 The collisions take places in a vacuum chamber.
2 The tracker gauges the momentum of particles before they travel **through the outer layers.**
3 The electromagnetic calorimeter stops photons and electrons to measure **their energy levels.**
4 The hadronic calorimeter stops and measures any particles made from quarks, **which make up protons and neutrons.**
5 The superconducting coil solenoid generates a magnetic field at the collision site. This **bends the path of particles, making** it possible to identify and measure them.
6 The return yolk (12,000 tons of iron) contains the magnetic field, which is 100,000 times more powerful than the Earth's.
7 The muon chambers track the path of (you guessed it) muons. These are charged particles that scientists expect will be produced when unknown particles, like the Higgs boson, decay following collisions.

How does it work?

The collision process begins with either hydrogen or lead. To produce a proton stream, operators strip electrons away from hydrogen atoms. To produce an ion stream, operators heat lead atoms to 550 degrees celsius and then pass the lead vapour through an electric current to ionise it.

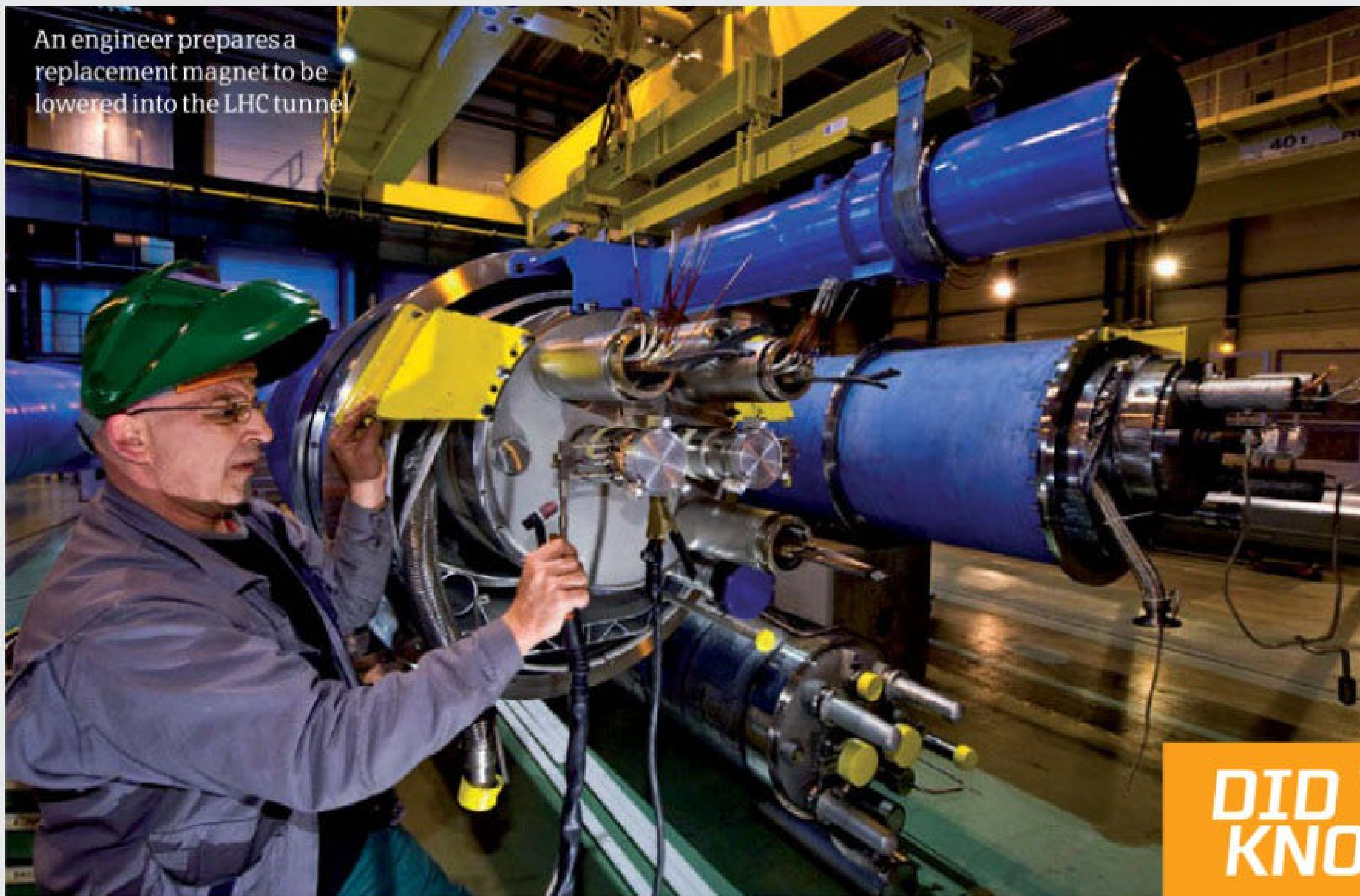
Once the particles are ready, the operators pass them through an accelerator chain outside the LHC track itself. This chain applies radio frequency electrical fields to energise the particles (get them up to high speed), before injecting them into the LHC's circular "beam pipe" tracks.

As the beams zip around the pipes, in a ultra-high vacuum, they pass through periodic radio frequency cavities. These cavities produce electrical fields that energise the particles, keeping them moving at top speed. The pipes intersect at various collision points around the LHC ring, and the particles collide. Detectors at the intersection points register what happens.

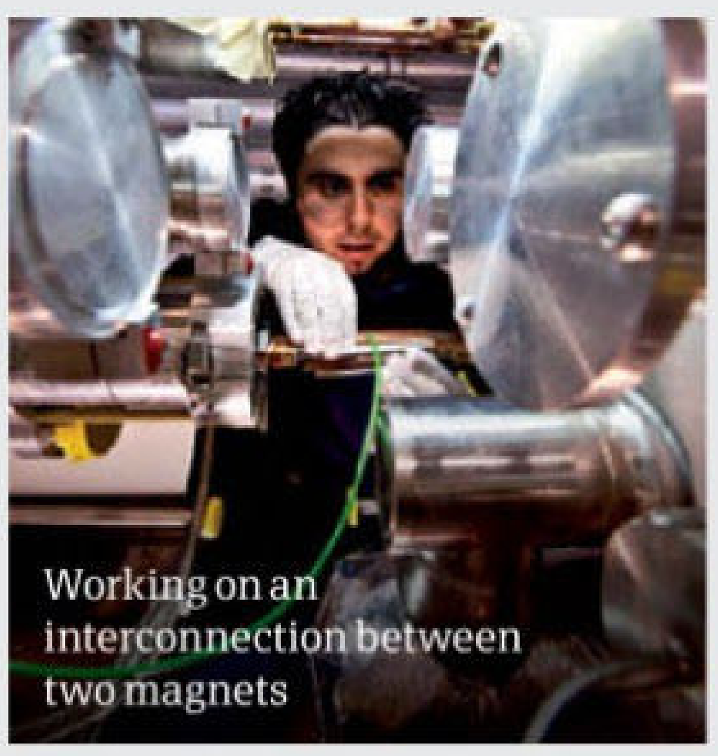
The biggest engineering challenge is guiding the particles – that is, steering them along the circular track and focusing them into beams. The LHC does this with powerful electromagnets, which generate magnetic fields to push the particles in the right direction. There are a total of 9,300 magnets in the LHC, including 1,232 15-metre-long dipole magnets that bend the beams so they follow the track, and 392 five to seven-metre magnets that focus the beams.

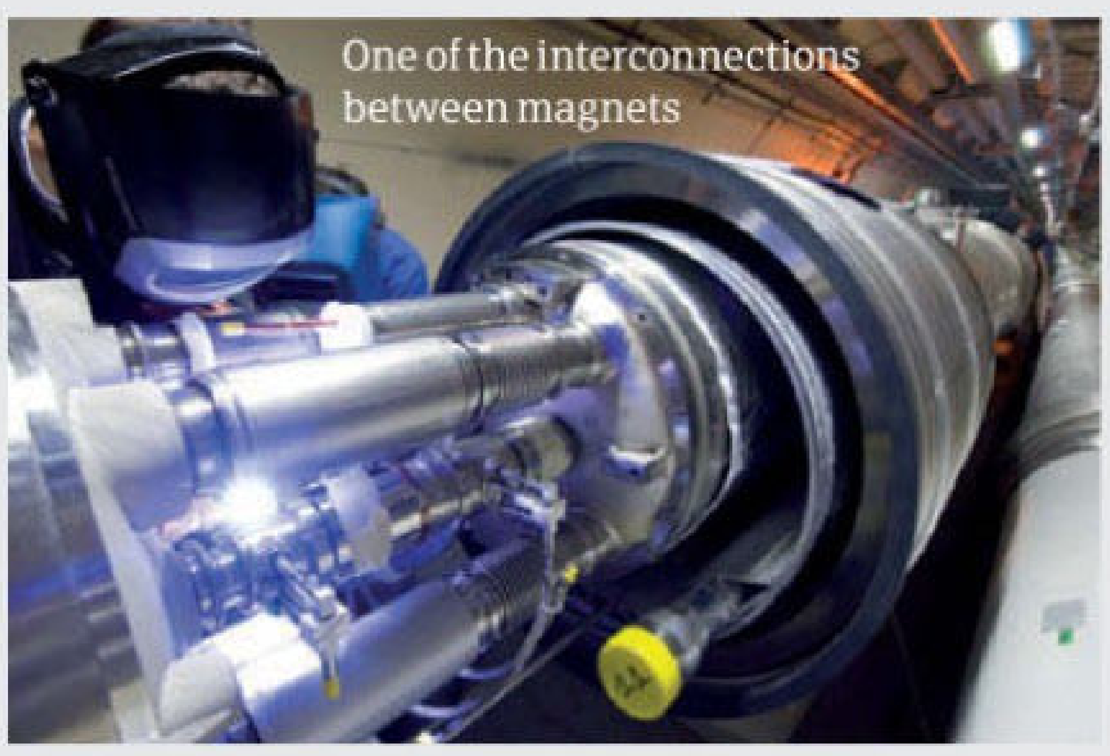
A conventional electromagnet consists of a coil of wire, hooked up to a power source that produces an electrical current. The current in the wires generates a magnetic field, thanks to the electromagnetic effect. In the massive LHC, the energy consumption for this type of electromagnet would be prohibitively expensive. Instead, the LHC sports supercooled superconducting electromagnets made from niobium-titanium cable. Niobium-titanium is a superconductive metal, meaning that if you keep it cold enough, it offers no electrical resistance and sustains an electrical current indefinitely. In other words, you can use it to create electromagnets that continually carry a current (13,000 amps, in the case of the LHC), while consuming no power whatsoever.

The catch is that you have to keep the magnets incredibly cold. To do this, engineers first cool the magnets to -193.2 degrees celsius, using liquid nitrogen. Next, they cool the magnets down to a steady -271 degrees celsius, using an advanced refrigeration system. This system, essentially the biggest fridge in the entire world, uses superfluid liquid helium as a coolant.


An engineer prepares a replacement magnet to be lowered into the LHC tunnel


Engineers check connections on a dipole magnet

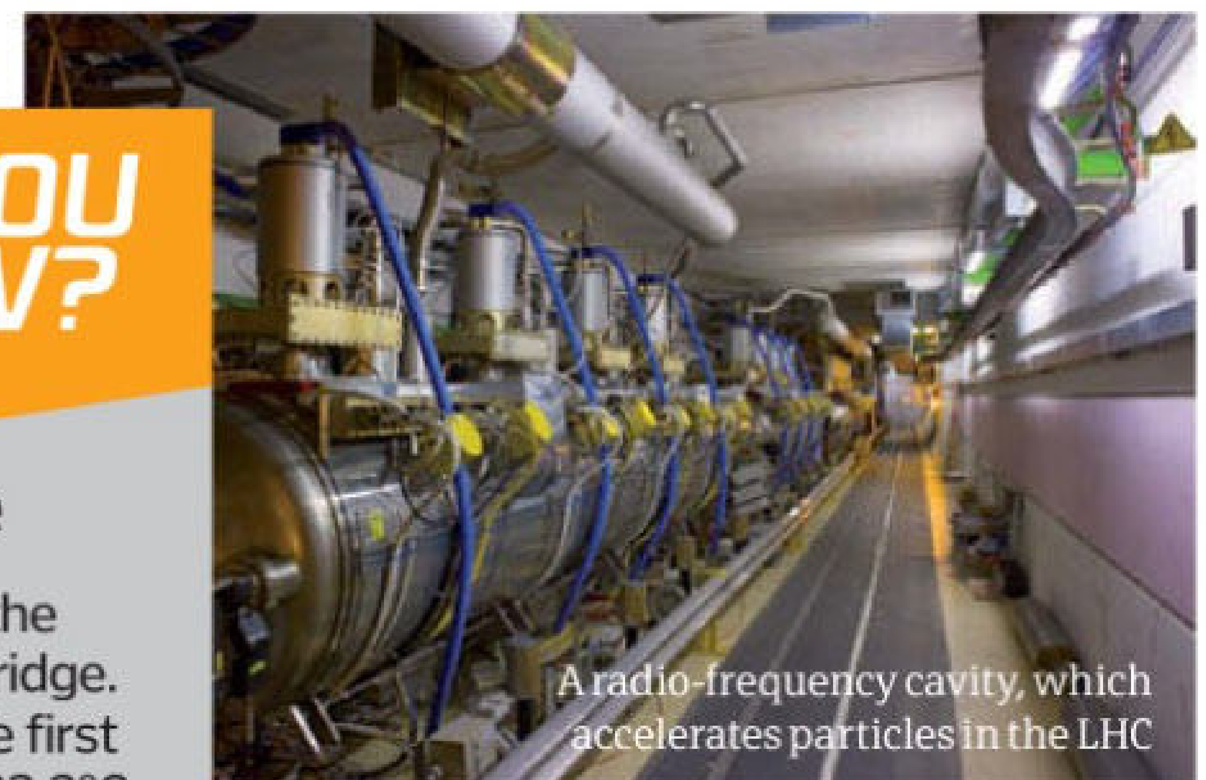

Working on an interconnection between two magnets


One of the interconnections between magnets

DID YOU KNOW?

Big fridge

The LHC is also the world's largest fridge. The magnets are first pre-cooled to -193.2°C using liquid nitrogen before nearly 60 tons of liquid helium bring them down to a rather frosty -271.3°C.


A radio-frequency cavity, which accelerates particles in the LHC


Installing the beam pipe in the middle of the ATLAS magnet doughnut

Trouble in the tunnel

Given the enormous complexity of the LHC, the malfunction in September of 2008 wasn't a total shock. We talked to the man in charge of the LHC magnets, Lucio Rossi, to find out what happened.

Rossi explained that the engineers were able to test some parts of the LHC ahead of time, but not everything. "To be sure that the magnet works, we tested them between 2002 and 2006," Rossi said. "But what we couldn't test was the connection between the magnets – the assembly of the magnets – the 27-kilometre long ring."

These interconnections turned out to be a weak link, which in turn led to major malfunction. "The 13,000 amp current has to pass from one magnet to another," Rossi explained. "To do this, there is a special joint, or splice. One of these failed and overheated."

The engineers didn't recognise the problem right away, and the connection heated from -270 degrees celsius up to 800 degrees, essentially melting away. Things got even worse when a 9,000-amp electrical arc formed between the magnets. "A lot of power went into the arc," Rossi said, "and so everything melted in this zone between two magnets."

As a result, the super-fluid helium from the cooling system leaked into the vacuum, forming a powerful pressure wave. "Because of this pressure wave, we had magnets that were pushed, literally pushed," Rossi explained. "These weigh 30 metric tons and they were pushed, some of them a half a meter, some of them only two centimetres."

The malfunction ended up being fairly substantial: "We had to remove and repair and substitute a lot of magnets. In total, we removed 53 magnets – a line of magnets more or less 700 metres long. So, 700 metres of the accelerator has been completely repaired. All the magnets have been removed, either repaired and put back again, or completely substituted with brand new magnets," stated Rossi.

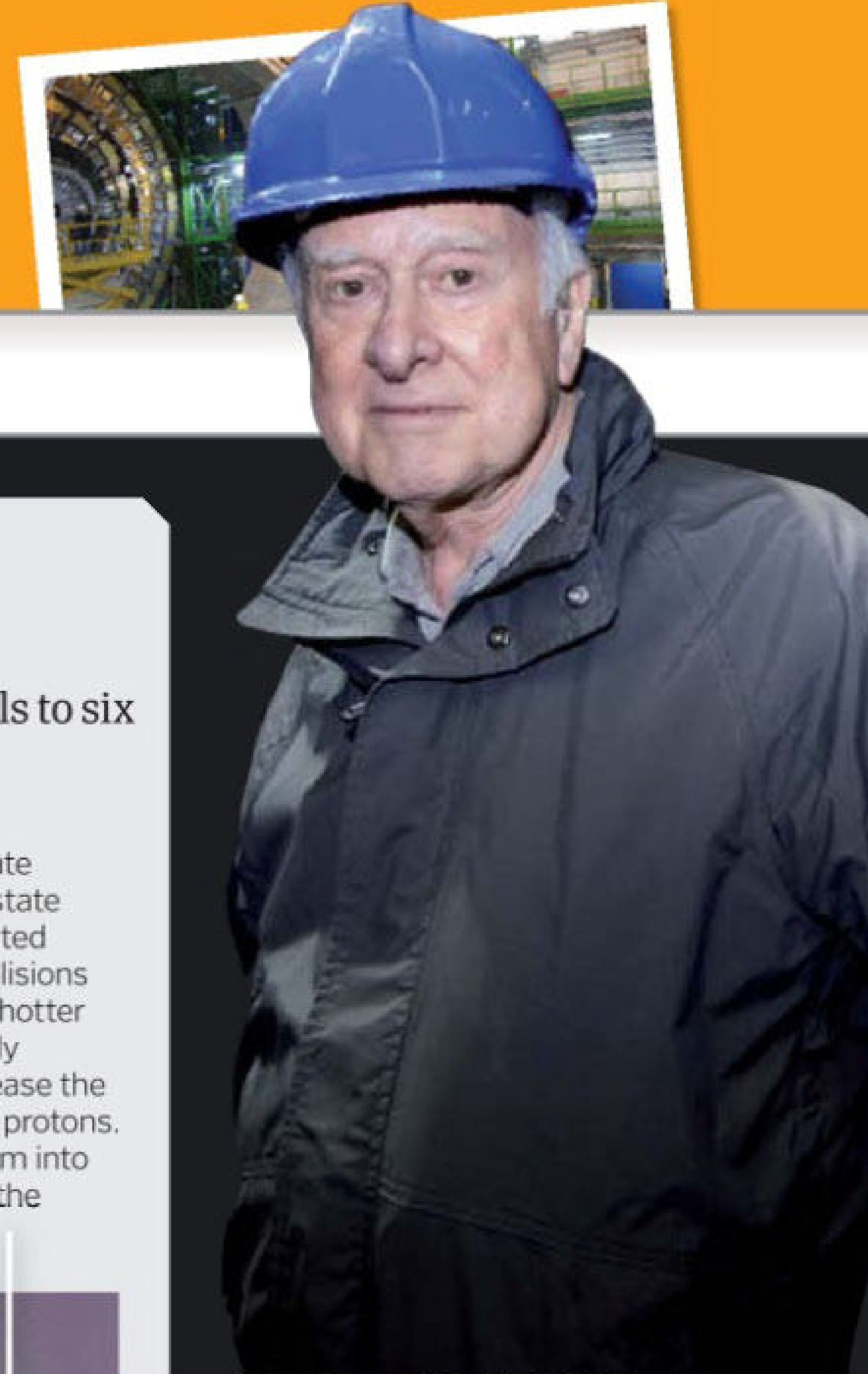
The supercooling system added to the repair time. It took about a month just to warm the magnets to the point that the engineers could handle them. Additionally, the engineers had to remove all the damaged magnets from their cryostats – advanced thermos systems that help keep the magnets cool. According to Rossi, the repair work took eight to nine months, and involved around 300 people.

What's next?

The LHC engineers had everything replaced and in working order by early July, but they still had to cool the magnets to operating temperature. This takes about a month per section, which pushed the re-launch date back to November.

For the next year or two, the LHC will be operating at only half power. But, Rossi clarified, even that is monumental. "It's already new land, new exploration, new physics. But we don't want to strain it too hard, because of the intrinsic weakness in our interconnections system. So, we are already designing a project to seek all the necessary modifications to be able to push the accelerator to the maximum power."

At that point, the LHC will move trillions of hadrons fast enough to make a full lap 11,245 times a second. It could be years before the LHC yields new discoveries, but it should keep a lot of scientists very busy and very happy in the meantime.



Peter Higgs visits the ATLAS experiment, which may finally find the Higgs boson

DID YOU KNOW? *The ATLAS cavern could hold the nave of Notre Dame cathedral*

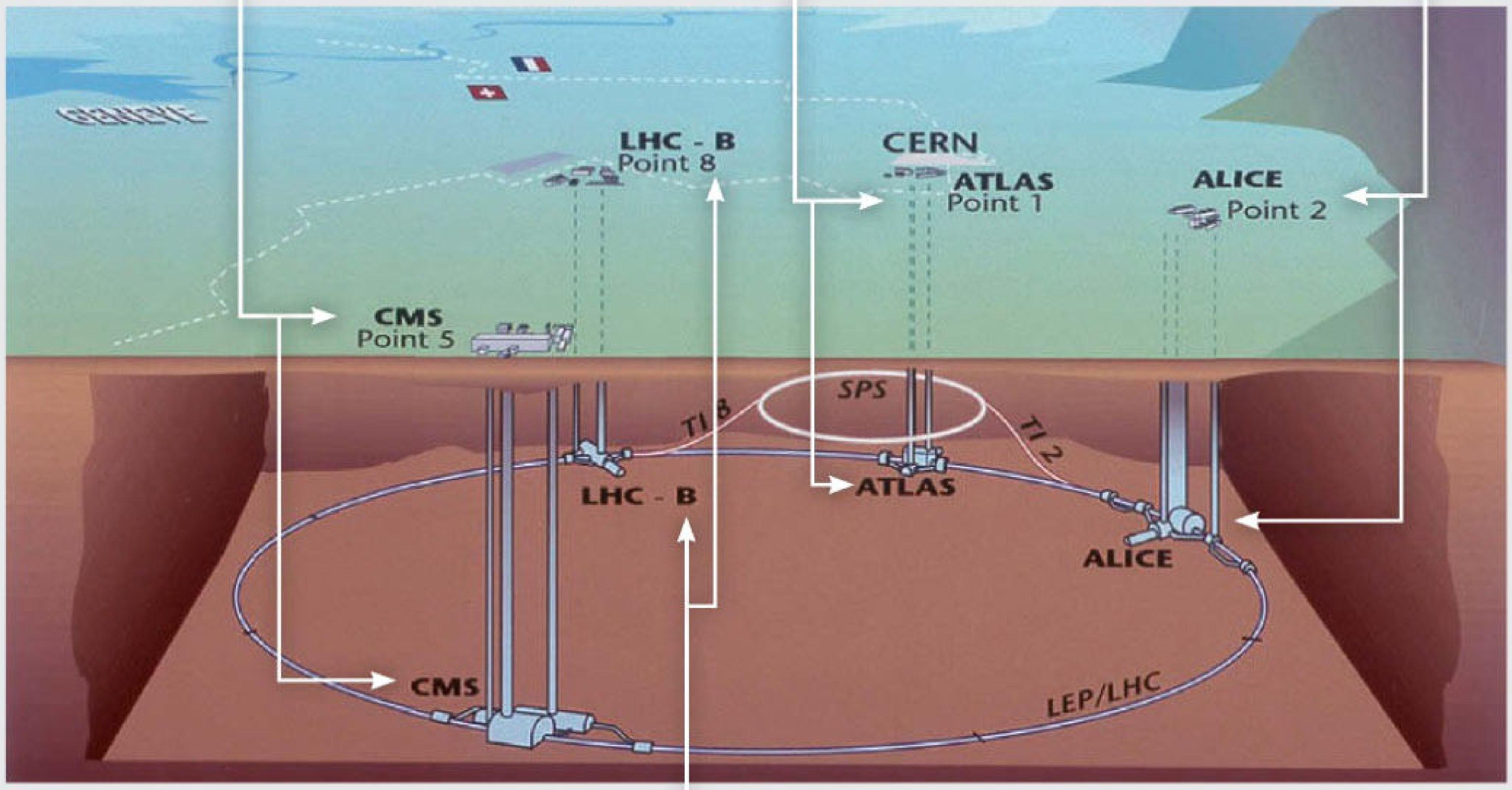
Know your LHC experiments

There's not much point in smashing particles together if you don't record what happens. This work falls to six advanced detectors, spaced out around the LHC ring. Each detector is part of a different experiment

1 CMS (Compact Muon Solenoid) serves the same basic purpose as ATLAS, but goes about it in a different way. Instead of a magnetic doughnut, it uses a giant solenoid -- a coil of superconducting cable. This solenoid can generate a magnetic field 100,000 times more powerful than the Earth's. A massive steel yoke contains the field.

2 ATLAS (A Toroidal LHC ApparatuS), the biggest detector, is like a giant doughnut, made from eight 25-metre superconducting magnetic coils that surround the beam pipe. It's a general detector, designed to dig up clues related to a variety of phenomena, including gravity, mass, dark matter, and extra dimensions.

3 ALICE (A Large Ion Collider Experiment) is designed to create and observe quark-gluon plasma, a state of matter that scientists believe existed soon after the Big Bang. Lead ion collisions will generate energy 100,000 times hotter than the centre of the Sun, essentially melting the protons. This should release the quarks and gluons that make up the protons. As this plasma cools, it should re-form into atoms, in the same way it did when the universe was forming.



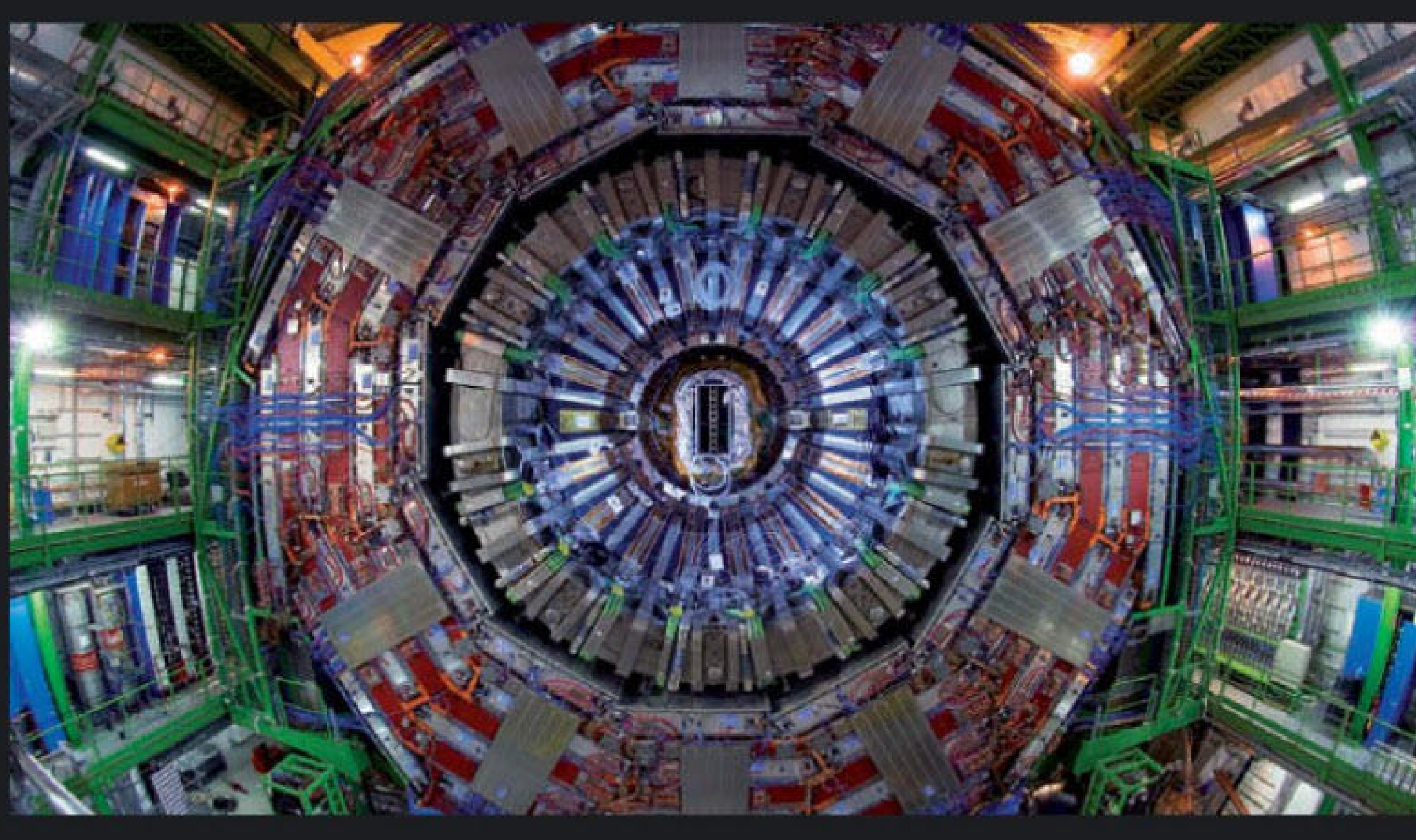
4 TOTEM (TOTal Elastic and Diffractive Cross Section Measurement) is designed to measure particles very near the beams, in order to gauge proton size and the LHC's performance, among other things.

5 LHCb (Large Hadron Collider beauty) consists of a series of sub-detectors designed to examine a type of particle called a 'beauty quark'. The hope is observations of these particles will shed light on the relationship between matter and antimatter.

6 LHCf (Large Hadron Collider forward) is the smallest experiment of the bunch. The idea here is to observe cascades of particles caused by LHC collisions to gain a better understanding of cosmic rays, charged particles from space that create similar cascades when they encounter Earth's atmosphere.

Too much information

With 150 million sensors capturing data 40 million times a second, the LHC will produce a phenomenal volume of information for scientists to analyse. Specifically, the four experiments will result in 15 million gigabytes of data per year – that's equivalent to a 20-kilometre stack of CDs. This is too much for any one computer to handle, so CERN will rely on "The Grid" – thousands of computers from around the world that are networked together via the net.



The hunt for Higgs

Whether or not scientists find it, one of the biggest stars of the LHC will be the Higgs boson. In 1964, physicists Peter Higgs, Robert Brout, and François Englert proposed this theoretical particle as a possible explanation for one of the biggest mysteries in physics – why some particles have mass and others don't.

The physicists proposed that just after the Big Bang, particles had no mass. But as the universe cooled, a force field formed that had the ability to give particles mass. Whenever a particle encounters this 'Higgs field' it gains mass from a particle called a Higgs boson. This gels well with other theories, but scientists haven't been able to confirm that the Higgs boson exists. If it's real, the LHC should reveal it. And if it doesn't show up, physicists will get a nudge to pursue alternative theories.

Learn more

For more information about the Large Hardon Collider, visit **http://public.web.cern.ch/public/**, the official website for the European Organisation for Nuclear Research. You can find news and information on all the LHC experiments.

This plane should not be able to fly…

This month in **Transport**

Anything that travels by road, rail, sea or air gets explained in this section. If you've ever wondered what lies beneath the hull of the Royal Navy's most deadly and most expensive nuclear submarine then you'll find the answer in out launch issue. Take a look at the fantastic cutaway on page 50...

44 Fastest car on Earth

46 Ejector seats

48 The deadliest sub

TRANSPORT

Eurofighter Typhoon

The fighter plane that is so advanced it can't be flown by a human without the help of a computer

Picture courtesy of BAE Systems

Under construction
The building of a Typhoon is certainly no easy task...

"It is impossible for a human to fly the plane without the aid of a complex computer system that makes constant adjustments to the wings' flaps"

Eurofighter in action

Just what makes the Eurofighter so formidable?

The Eurofighter Typhoon may be the world's most advanced killing machine, but it is also an extraordinary symbol of peace and co-operation. After centuries of fighting, a handful of European countries came together to produce this incredible aircraft.

From a plan started as way back as 1979, the Eurofighter was developed by Germany, Italy, Spain and the UK (France was involved for a while but then snuck off to do its own thing), and production is split between the four countries. At present there are plans to produce no less than 707 examples of the fighter jet. As well as the four core countries, the plane is also being used by other air forces around the world, including those of Austria, Saudi Arabia and Greece.

Why? Because it's quite simply the most technologically advanced fighter jet on the planet, and also the most capable.

It's what's known as a swing-role weapon system, which means that it is capable of different operational tasks and can even switch from one duty to another on a single mission. For instance, it can be used as an air-to-air (short and medium range) fighter to gain all-important air superiority, while at the same time carrying large, long-range ground-attack weapons for taking out an enemy's air defence systems.

This flexibility is further enhanced by the plane's incredible flying prowess. It boasts STOL (short take-off and landing) which means that it needs just 700 metres to take-off or land (the 747 you go on holiday in requires over 3,000 metres).

More impressively, the Eurofighter is incredibly manoeuvrable. This is thanks in part to its 'relaxed stability' design, which is a reassuring way of saying that the aircraft is inherently unstable, especially at subsonic speeds. Put simply, the plane's delta wings and small fore fins create a pressure (lift) point which is forward of the centre of gravity during subsonic flight. And that means it is impossible for a human to fly the plane without the aid of a complex computer system that makes constant adjustments to the wings' flaps quicker than the pilot could. Once the speed of sound is broken, though, the pressure point moves back and the aircraft becomes much more stable (although the computer aids remain).

The same flight control systems also make the Eurofighter surprisingly easy to fly, therefore freeing up the pilot to concentrate on tactical tasks.

No wonder the Eurofighter Typhoon is changing the way the world's air forces think about fighter planes.

Armed and ready for action

The Eurofighter's formidable arsenal. The large items are, in fact, fuel tanks, although long-distance missiles can be fitted. The yellow devices are laser-powered bombs, while the smaller grey items are short-range air-to-air missiles. The thin armaments visible at the back of the fuselage are beyond-visual-range air-to-air missiles. There is also a Mauser BK-27 automatic cannon.

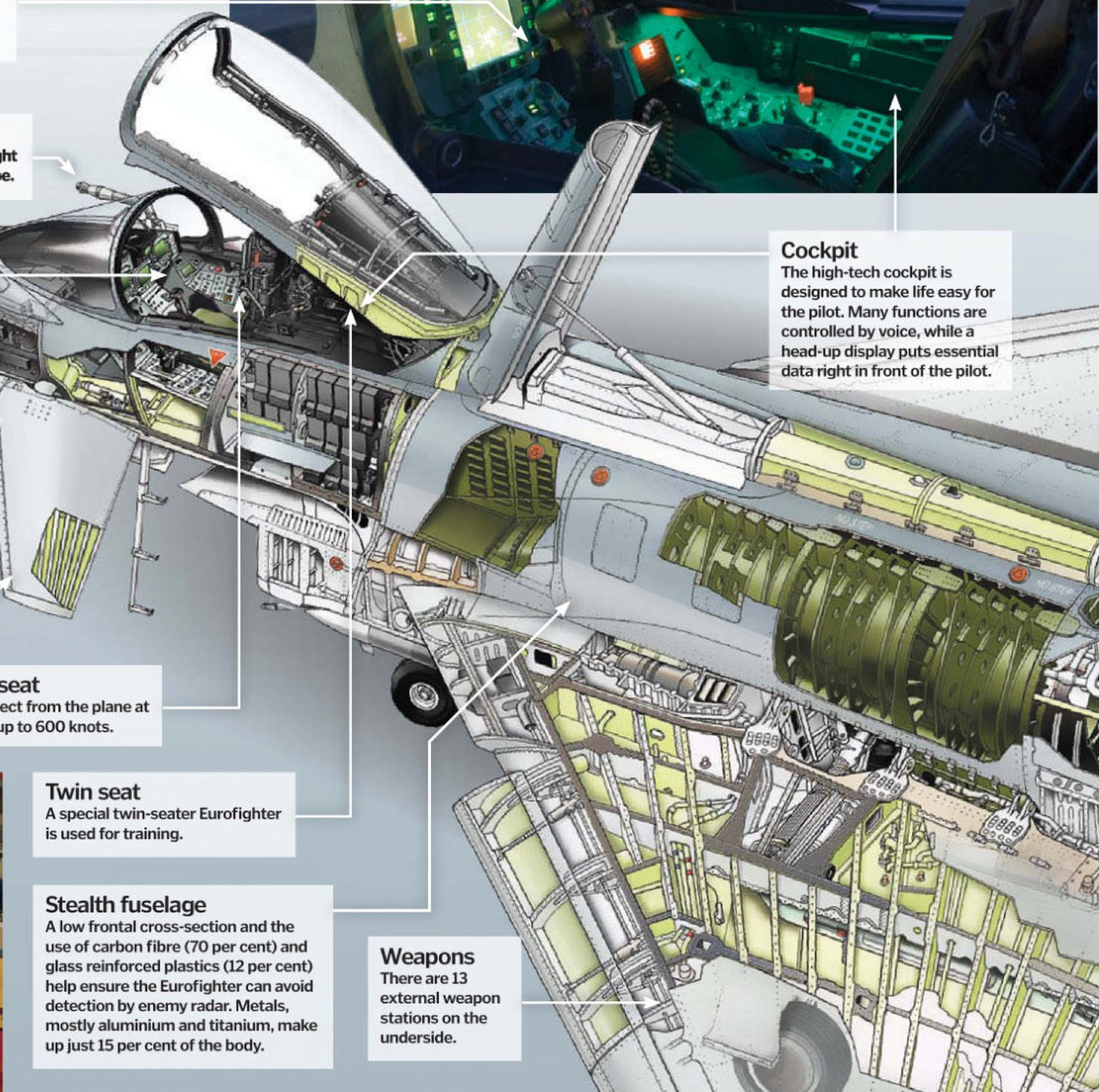
Small but perfectly formed

The Eurofighter is remarkably compact – look at the size of the pilot in the cockpit to get an idea. The wingspan is 10.95 metres (less than that of a WWII Spitfire) and the length is 15.96 metres. This helps the aircraft to be incredibly agile, allowing it to change direction fast, as well as accelerate at an astonishing rate.

Giving it full throttle

The Eurofighter's twin Eurojet turbofan engines combine a jet nozzle with a ducted fan. This allows efficiency at low speeds combined with relatively quiet operation. They are equipped with afterburners (shown in operation here) which inject neat fuel into the jet stream to give a short increase in power. However, the Eurofighter can cruise at supersonic speeds without afterburner help.

Inside the Typhoon



Joystick
The Hands on Throttle and Stick (HOTAS) is a single joystick that gives fingertip control of up to 24 functions, including throttle, manoeuvring, target manipulation and weapon control.

Radar
Advanced ECR-90 radar can track multiple targets at long range.

Front end
Includes in-flight refuelling probe.

Cockpit
The high-tech cockpit is designed to make life easy for the pilot. Many functions are controlled by voice, while a head-up display puts essential data right in front of the pilot.

Fore wings
Made from titanium, these aid agility and responsiveness.

Ejector seat
Pilot can eject from the plane at speeds of up to 600 knots.

Twin seat
A special twin-seater Eurofighter is used for training.

Stealth fuselage
A low frontal cross-section and the use of carbon fibre (70 per cent) and glass reinforced plastics (12 per cent) help ensure the Eurofighter can avoid detection by enemy radar. Metals, mostly aluminium and titanium, make up just 15 per cent of the body.

Weapons
There are 13 external weapon stations on the underside.

A stunning machine with awesome firepower

A top speed of 1,550mph means sights like this are common

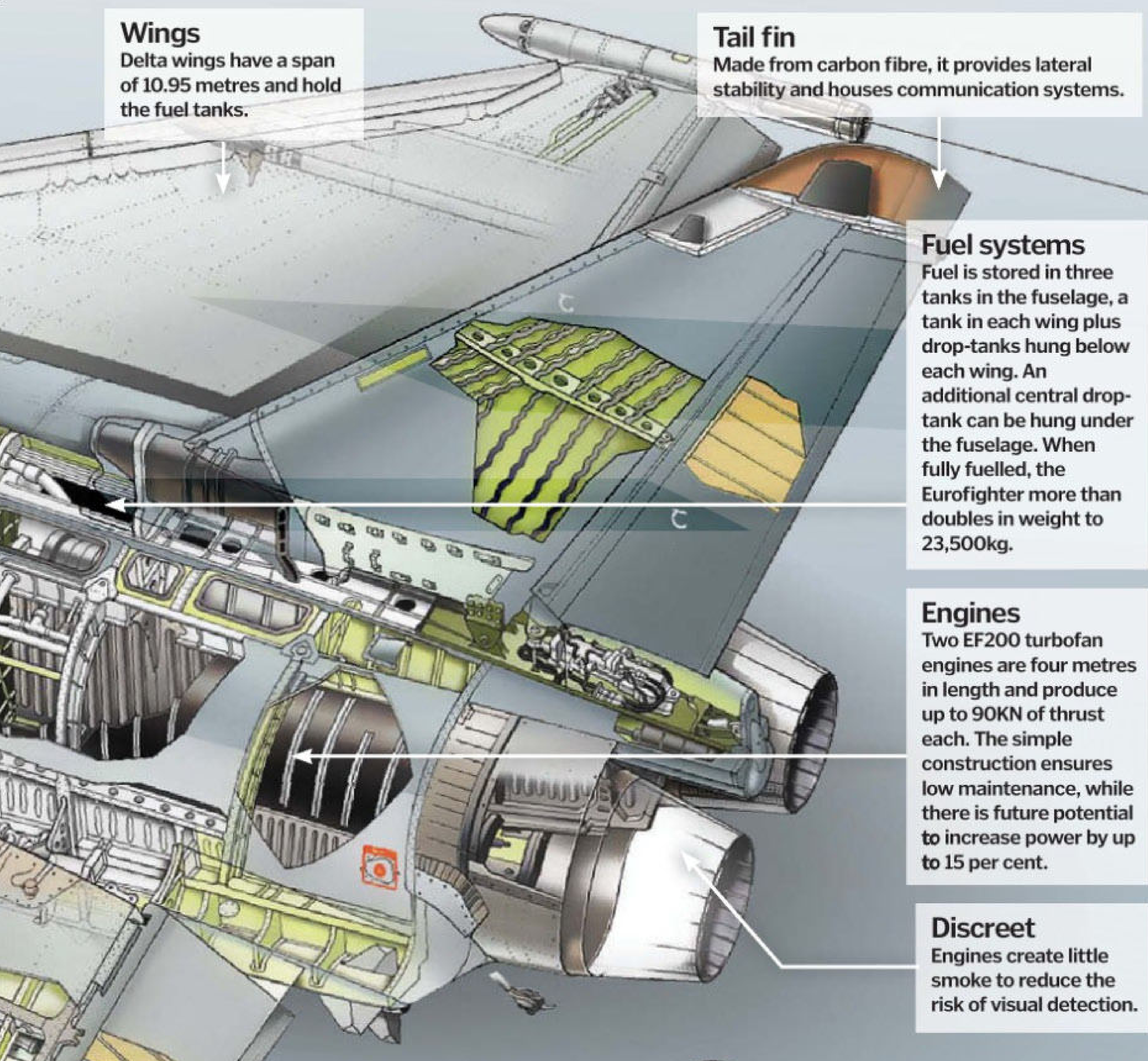
All pictures courtesy of Geoffrey Lee from planefocus

THE STATS TYPHOON

RANGE **2,045 miles** RATE OF CLIMB **315m/s** TOP SPEED **1,550mph**
WEIGHT **10,995kg** ALTITUDE **20,000m** CRUISE SPEED **750mph**

Take a look inside the Eurofighter

Find out what makes the Eurofighter Typhoon the most advanced fighter on the planet



Eurofighter VS F-22 Raptor

Engine Thrust:	20,000lbs
Max Speed:	1,550mph
Supercruise:	840mph
Altitude:	65,000 feet
Max Range:	2,045 miles
Cannon:	Mauser BK-27 (150 rounds)

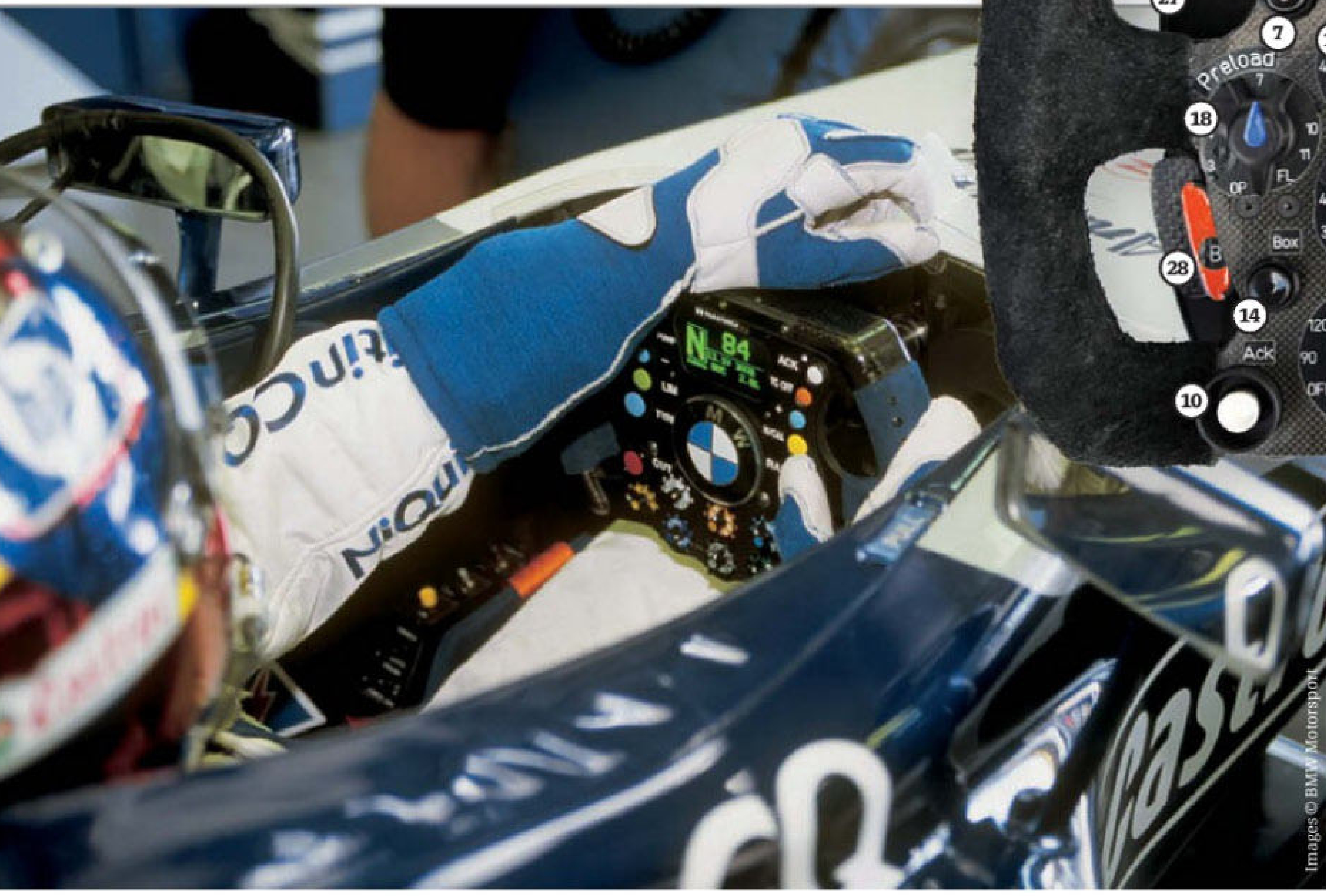
Engine Thrust:	35,000lbs
Max Speed:	1,500mph
Supercruise:	1,220mph
Altitude:	60,000 feet
Max Range:	1,840 miles
Cannon:	M61A2 Vulcan (480 rounds)

Typhoon vs F-22 Raptor

So after taking an in-depth look at Europe's most advanced fighter jet, the question of its performance against the American F-22 remains. It's an argument that rages on many an aviation-based internet forum and it's also one that is unlikely to ever have a truly real-world answer.

There's a very strong argument for USAF's F-22 Raptor having air dominance over the Typhoon because of its versatility: the Raptor has stealth capabilities and supercruises at a much higher speed than its European rival, which many agree would give it the edge in all but a WVR (Within Visual Range) encounter. Due to its tiny radar signature the F-22 could obliterate the Typhoon before the latter was even aware of its presence. However, development of the third phase of the Typhoon will endow the fighter with full strike capabilities and improved radar to match the Raptor. The cost of the Raptor is also worth weighing in the Typhoon's defence: initially £140 million for each Typhoon versus around $339 million (£212 million) for the Raptor, including research and development costs.

The most reliable source of comparison comes from General John P Jumper, Chief of Staff of the United States Air Force from 6 September 2001 to 2 September 2005 and one of the few pilots to have flown both aircraft. Speaking to the Air Force Print News shortly before he retired, General Jumper said "It's like asking us to compare a NASCAR car with a Formula 1 car. They are both exciting in different ways, but they are designed for different levels of performance." He continued, "The Eurofighter is certainly, as far as smoothness of controls and the ability to pull (and sustain high g-forces), very impressive," he said. "The manoeuvrability in close-in combat was also very impressive." All very complimentary, but on the question of dominance Jumper stated "The F-22 Raptor has stealth and supercruise," he said. "It has the ability to penetrate virtually undetected because of (those) capabilities. It is designed to be a penetrating aeroplane. It can manoeuvre with the best of them if it has to, but what you want to be able to do is get into contested airspace no matter where it is." However it would seem that the real measure of success between the two planes is a financial one. The US Senate discontinued production of the F-22 in July, with President Obama himself stating "at a time when we're fighting two wars and facing a serious deficit, [expanding the F-22] would have been an inexcusable waste of money". Conversely, back in May Prime Minister Gordon Brown committed to buying a third tranche of Eurofighters, perhaps making it a winner without even leaving the hanger.



Images © BMW Motorsport

MINI-GUIDE KEY

Parts of the steering wheel explained in this key guide

1. FIA/Race control
2. Shift lights
3. Multifunction display
4. Neutral
5. Activate front wing
6. Multipurpose button
7. KERS boost button
8. Presettings down
9. Presettings up
10. Acknowledge
11. Pitlane limiter
12. Spare
13. Radio
14. Pit stop
15. Clutch
16. Safety car
17. Differential
18. Differential settings
19. Differential
20. Cruise control
21. Selector
22. Tyre adaption
23. Presettings front wing
24. Pedal map
25. Fuel mix
26. Upshift
27. Downshift
28. Clutch

Formula One cockpit

The cockpit of a Formula One car is a high-tech and surprisingly safe place to be

The cockpit of a modern Formula One car is much more than just a place for the driver to sit – it's also his survival cell and an integral part of the car's structure.

The carbon fibre 'tub' of the car is the principal component of the vehicle and the engine and front suspension are attached directly onto it. This makes for a much lighter structure than having to rely on a separate chassis. As well as being stiff to cope with the forces involved when the car is driving at high speed around a track, the tub is also incredibly strong to protect the driver in the event of an accident. Today's FIA regulations insist on this, which is one reason fatalities are so rare in modern Formula One. The front and rear of the tub incorporate crash protection areas to absorb impact, and there is also a roll-hoop behind the driver's head. The sidewalls of the cockpit are as high as possible to protect the driver from flying debris.

The carbon fibre seat is made especially for the driver so that it is a perfect fit, and there is a five-point harness to hold him in place.

Regulations insist that, in an emergency, the driver be able to get out of the car in just five seconds, without having to remove anything but the harness and the steering wheel. And he must also be able to replace the wheel in the same time, in case the damaged car needs to be manoeuvred off the track.

The steering wheel holds all the controls (except for throttle and brake, which remain foot-operated) and instrumentation, so that they're immediately to hand. Formula One cars now have power-assisted steering, which allows the wheel to be very small.

Volkswagen's car vending machine

Glass and steel car towers are the centrepieces of Volkswagen's AutoStadt in Wolfsburg, Germany

AutoStadt (car city) is part factory, part dealership, and part theme park. All the elements come together in two 20-story car towers.

When a car rolls off the factory assembly line, a robotic rail system carries it to one of two 145-foot towers, which can each hold 400 cars. A robotic lift hoists the car with a hydraulic arm and deposits it into an empty compartment. When the buyer comes to pick up the car, the lift system retrieves the car and places it on a conveyer belt leading to the KundenCenter (customer centre). The system uses only 20 per cent of the land of a conventional parking lot with equal capacity. Each tower has two lifts, and can 'process' one car every 45 seconds. On average, the towers deliver 600 cars a day. All in all, it's an amazing machine. Just don't kick it if your car doesn't drop.

Image courtesy of DooMee

For **iPhone & iPod**

Logic3

The i-Station Rotate solves a rather annoying problem

Now doesn't that look better?

i-Station Rotate

No matter how good the sound, you could find yourself trying to watch a horizontal video on a vertical screen. This i-Station Rotate speaker dock has turned the problem around delivering a completely flawless, full bodied sound together with the option of revolving your iPhone or iPod to view the video content or to display it on your TV via the video out connection, all of which can be easily controlled by the remote from the comfort of your armchair.

Made for iPod

i-Station Rotate - It's flipping brilliant

Works with iPhone

Logic3 i-Stations are available from:
● Argos ● Bennetts ● Carphone Warehouse ● Comet ● Currys ● GameStation ● HMV ● John Lewis ● KRCS ● Maplin ● Micro Anvika ● Tec7 ● Tesco ● Toys R us ● WHSmiths ● Amazon ● iWorld.co.uk ● Play.com

www.logic3.com

"The top speed of the Veyron is limited – if that's the right word"

How is the Bugatti Veyron so fast?

The fastest car in the world… Bugatti

There are supercars and then there is the Bugatti Veyron. Faster, more power and more advanced than anything that came before it, the Veyron is truly the ultimate car

When Volkswagen decided in 1998 to resurrect the famous Bugatti name, it didn't hold back. The Veyron redefined the term supercar with power and torque figures unlike anything that has come before it.

Let's cut straight to the chase. The Veyron's mid-mounted engine produces over 1,000bhp. Actually, the official figure is 'only' 987bhp, but in reality the output is believed to be closer to 1,035bhp. Indeed, an indicator on the dash lets you know when the power reaches the magic four-figure number (if you dare look because you are likely to be travelling at over 200mph when this happens…). But perhaps even more impressive is the engine's torque figure of 1250Nm; that's almost double that of the McLaren F1, itself previously the world's fastest car.

Those impressive figures come courtesy of an impressive engine, with no less than 16 cylinders arranged in a 'W' configuration (essentially, two V8s joined at the crankshaft). The capacity is a hearty 8.3-litres and the cylinders are fed by no less than four turbochargers. And to keep it all cool, there are ten radiators and two independent cooling circuits.

The power is fed to all four wheels through a seven-speed gearbox with the option of automatic or manual shifts, the latter courtesy of steering wheel-mounted paddles. And the power is then harnessed back by a set of massive ceramic disc brakes.

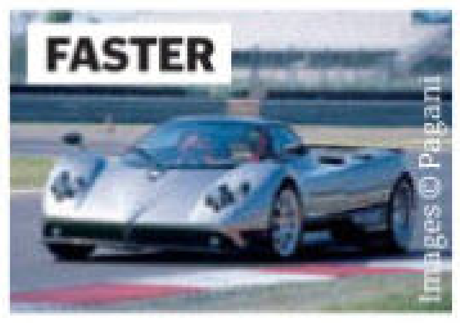
All this technology is clothed in an astonishingly beautiful body hand-made from carbon fibre and aluminium. It is undoubtedly a modern car, yet the designers managed to incorporate some of the old Bugatti charm into its lines; not least with the evocative radiator grille and badge. And, of course, the shape was defined by aerodynamic requirements to ensure that the car remains firmly on the road. Inside, the Veyron is pure luxury, with no plastic to be seen anywhere. Instead, you find leather and aluminium, all hand-crafted. Even the hi-fi unit has bespoke aluminium controls.

The top speed of the Veyron is limited – if that's the right word – to 253mph because the tyres are not considered capable of faster speeds. No one knows what the car is truly capable of. Surely, in these politically correct days, no one will ever have the tenacity to produce a more outrageous machine.

MID-MOUNTED ENGINE
8.3-litre W16 engine is mounted in the centre of the car to ensure good weight distribution which in turn helps ensure superb handling.

CERAMIC BRAKES
Massive brake discs are made from carbon fibre-reinforced silicon carbide, which is less likely to fade under heavy use, compared to steel discs.

1. Bugatti Veyron EB 16.4
Capacity: 8.3-litre **Cylinders:** W16
Max power: 987bhp
Max torque: 1250Nm
Gearbox: Semi-auto, six-speed
0-60mph: 2.9 seconds
Max speed: 253mph



Images © Pagani

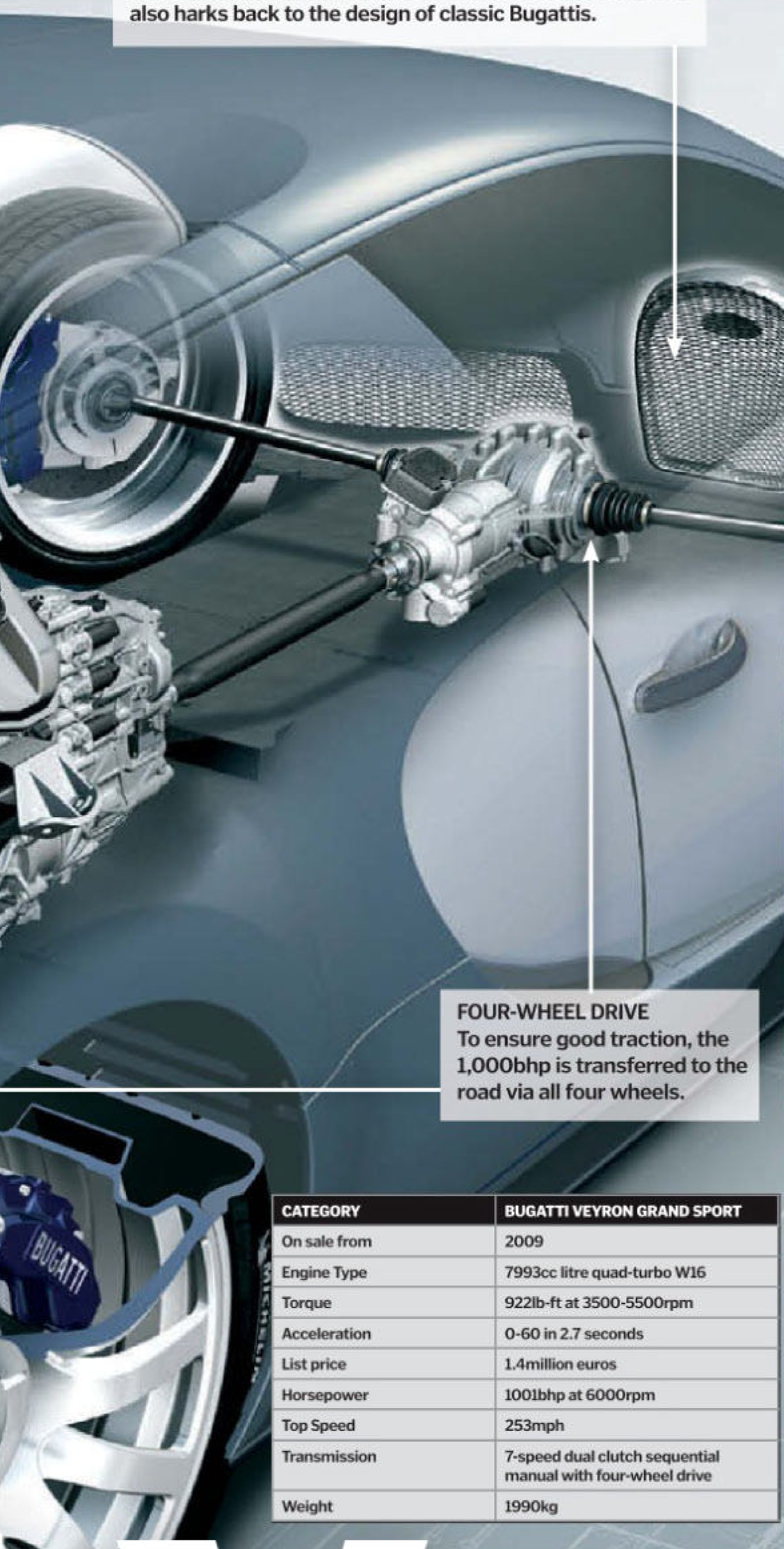
2. Pagani Zonda C12 F
Capacity: 7291cc **Cylinders:** V12
Max power: 620bhp
Max torque: 400Nm
Gearbox: Six-speed manual
0-60mph: 3.6 seconds
Max speed: 214mph

Images © McLaren

3. McLaren MP4-12C
Capacity: 3800cc **Cylinders:** V8
Max power: 600bhp
Max torque: 572Nm
Gearbox: Semi-auto, seven-speed
0-60mph: 3.4 seconds
Max speed: 200+mph

DID YOU KNOW? The Veyron was named after the French racing driver, Pierre Veyron, who won the 1939 Le Mans race

Inside the Bugatti
What makes the Veyron purr?



RADIATOR GRILLE
The central air intake is one of a number of apertures that feed air to the various radiators and intercoolers. This one also harks back to the design of classic Bugattis.

The W16 configuration enables a compact engine. Interestingly, the original Bugatti concept car of 1998 used a W18 engine

HIGH-SPEED TYRES
Michelin tyres were specially developed to cope with a 250mph top speed and also offer superb grip. They can run flat for around 125 miles – but only at 50mph.

FOUR-WHEEL DRIVE
To ensure good traction, the 1,000bhp is transferred to the road via all four wheels.

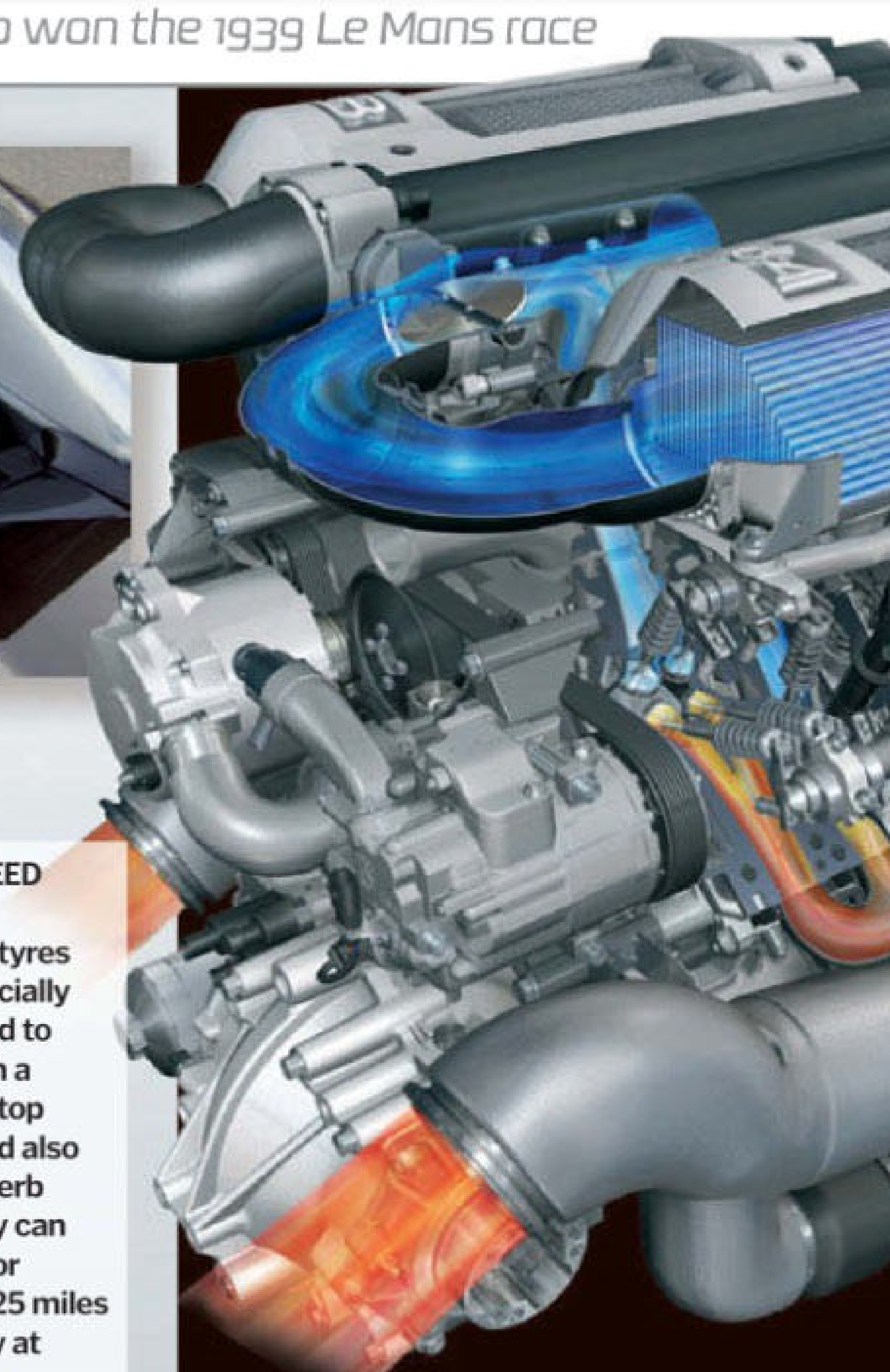
Images © Bugatti

Veyron Grand Sport

CATEGORY	BUGATTI VEYRON GRAND SPORT
On sale from	2009
Engine Type	7993cc litre quad-turbo W16
Torque	922lb-ft at 3500-5500rpm
Acceleration	0-60 in 2.7 seconds
List price	1.4million euros
Horsepower	1001bhp at 6000rpm
Top Speed	253mph
Transmission	7-speed dual clutch sequential manual with four-wheel drive
Weight	1990kg

Unveiled in August 2008, the first Bugatti Veyron Grand Sport was sold at a charity auction for $2.9 million, though main production didn't start until early 2009. Essentially there's no difference between the original car and the Grand Sport, though the first Bugatti Veyron proved so popular (*Top Gear* endorsements withstanding) that it's spawned several special edition models since. This latest in the Bugatti line is a targa top, with a removable roof for a top speed of 228mph and a folding umbrella roof that can be activated in case of rain, for 80mph max. Considering you could probably hit this speed simply resting your foot near the accelerator, you're going to want to take it somewhere reliably hot.

Veyron

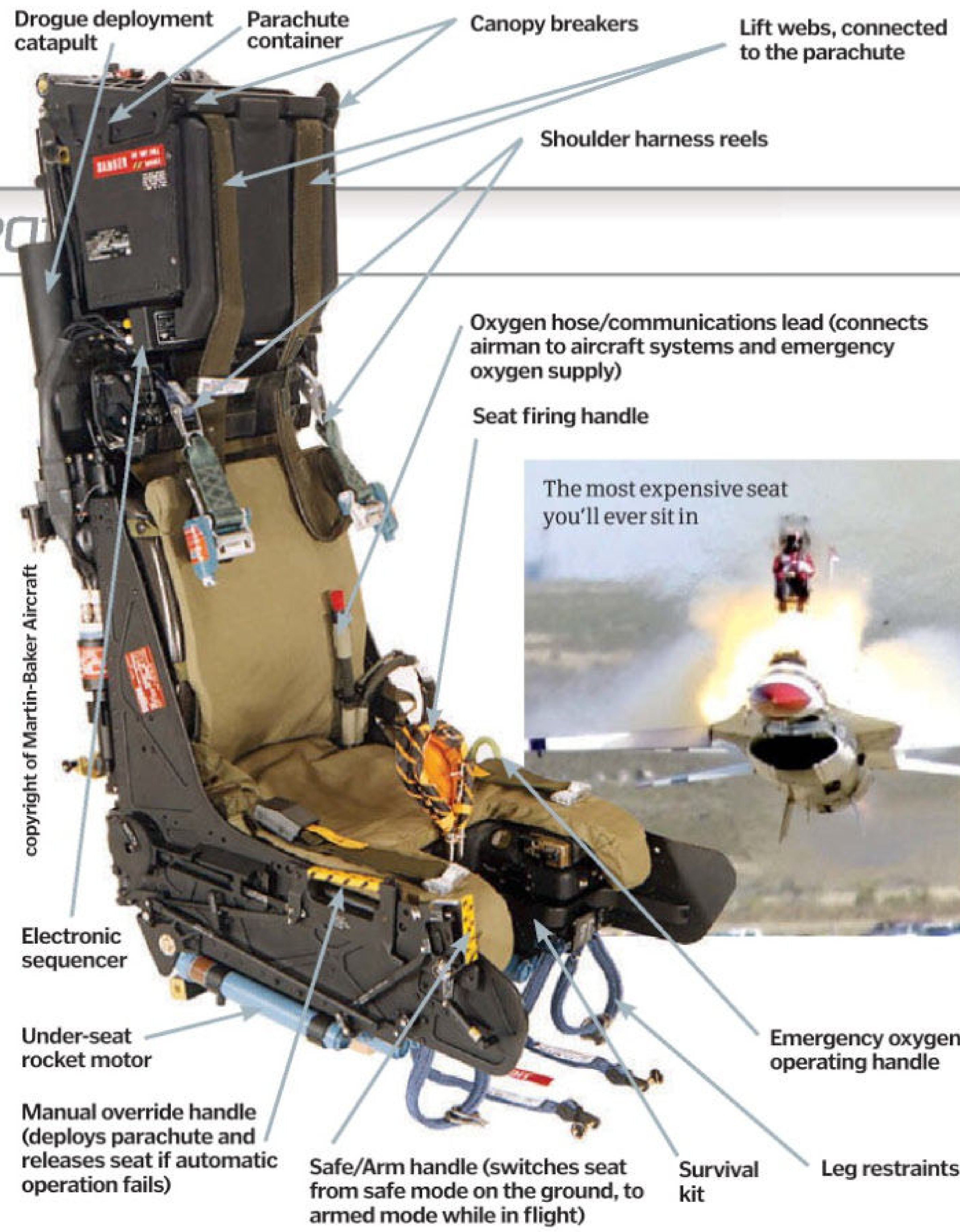


Under the hood
How does it make so much power?

The Veyron's engine is unusual in that it is has a W16 configuration – most supercars have a V12 engine. However, a V12 which produced 1,000bhp would have been restrictively large – both in capacity and in physical bulk, which is not ideal for a sports car. By using a W16 layout, Bugatti's engineers were about to create an engine that was relatively compact (it measures just 710x889x730mm) and limited to 8.3-litres.

However, that alone would not be enough to create the desired power, which is why the Veyron's engine has four turbochargers – one for each bank of eight cylinders. These use the otherwise wasted exhaust gases to force air and fuel into the cylinders.

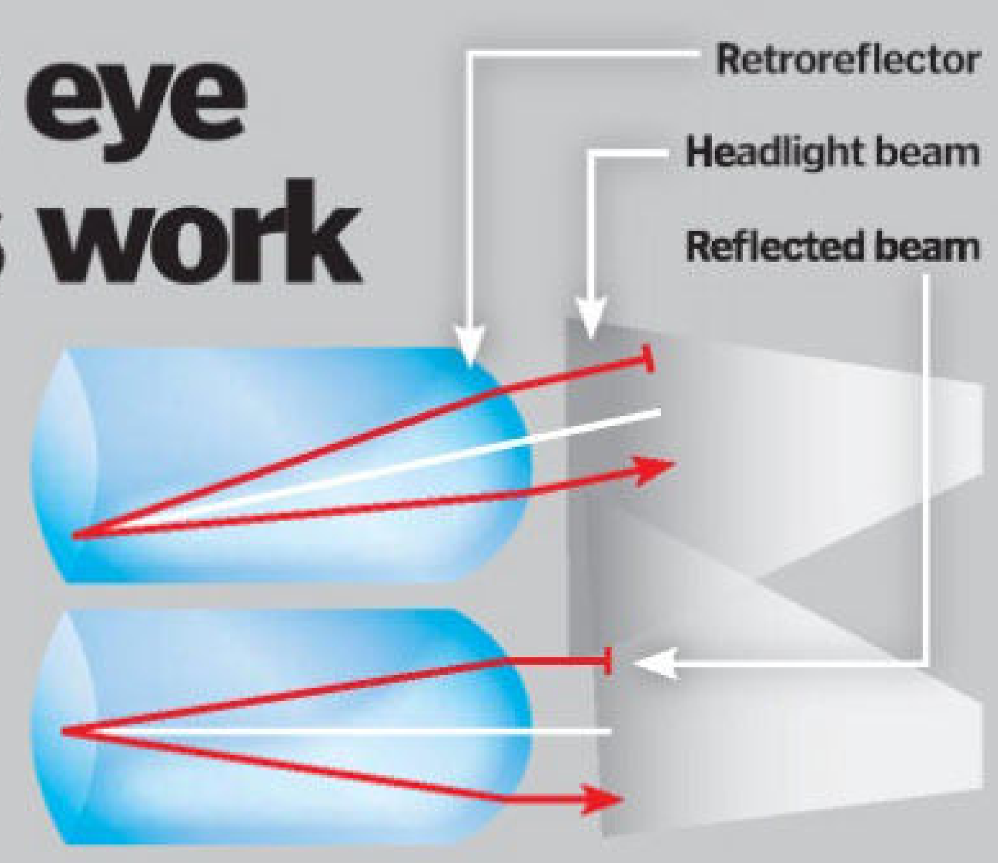
And how the Veyron drinks fuel! Using standard Combined Cycle tests, it manages to travel just 11.7 miles on one gallon of super unleaded. Floor the throttle, though, and that figure drops to an eye-watering 2.5mpg. In other words, its rather modest 100-litre tank would be drained in just 12 exhilarating minutes!



The most expensive seat you'll ever sit in

How cat's eye reflectors work

Since the Thirties, the simple cat's eye has been guiding our way



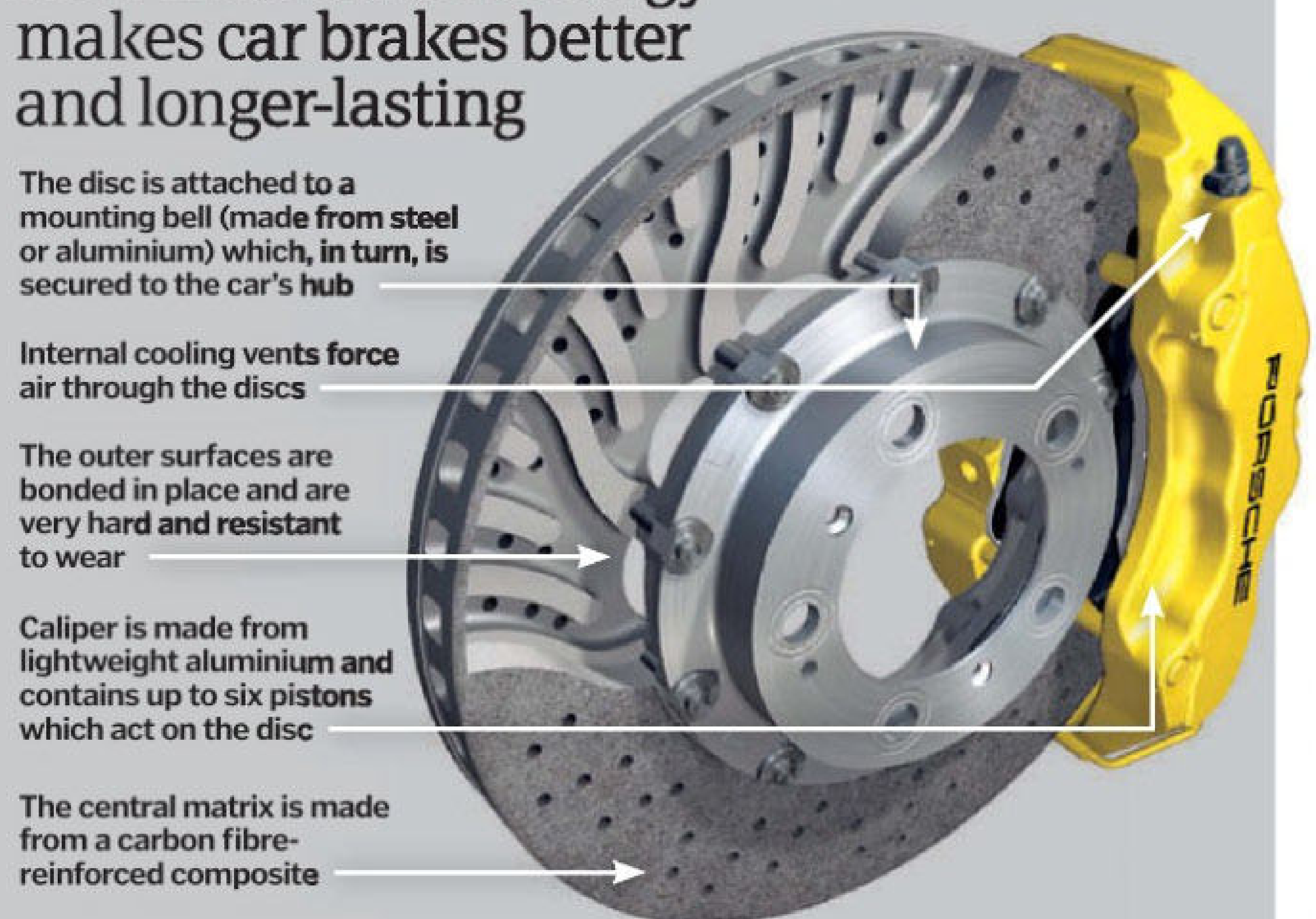
Legend says we have an actual cat to thank for these reflectors. One foggy night in 1933, Percy Shaw nearly ran off the road on his way home to Halifax. But a cat's eyes reflected his headlights, saving his life and sparking an idea (Shaw later credited a reflective billboard as his inspiration, however).

The original design uses spherical glass retroreflectors (devices that reflect light back toward its original source). The front of the sphere acts as a convex lens, focusing a beam on the back of the sphere. The back acts like a concave mirror, reflecting the rays parallel to their original direction.

Shaw's design also cleans itself. The reflectors sit in a rubber block, resting in a metal housing. When a car drives over the block, it sinks into the housing, submerging the reflectors in rainwater and brushing them past built-in wipers.

Ceramic brakes in-depth

How modern technology makes car brakes better and longer-lasting



Most car brakes use discs made of cast steel. However, there is a new material which offers advantages over steel discs.

Ceramic discs are generally made from carbon fibre-reinforced silicon composite – silicon being a very hardwearing material, and the carbon fibre gives it the necessary reinforcement.

The material is lighter than steel, and typically shaves about 20kg from the weight of a car. Moreover, it dissipates heat better than steel which means that the brakes' performance is not compromised during heavy use. It is also less susceptible to wear and corrosion, so ceramic discs have a much longer life span. Dirty brake dust is also eliminated.

The driver will notice improved braking ability and more 'feel' through the brake pedal, allowing him to modulate the braking force more accurately.

When all else fails: ejection seats explained

Since their 1942 debut, ejection seats have saved thousands of lives

In a worst case scenario, a pilot can pull a seat firing handle, initiating the ultimate hasty exit – an automated ejection sequence. In the pictured Martin Baker Mk 14 seat, a thermal battery-powered electronic module precisely controls much of the sequence.

First, the system retracts the harness and leg restraints, cinching the airman against the seat to reduce injuries. Explosive bolts fire along the canopy above the airman, jettisoning it from the aircraft. If this fails, sharp 'canopy breakers' at the top of the seat shatter the glass.

Next, the system fires explosive charges in a catapult assembly on the back of the seat. Gas pressure in the catapult propels the seat up along rails, out of the aircraft. The system severs connections to the aircraft, and activates an emergency oxygen supply and radio beacon in the seat. Then the system ignites a rocket motor pack under the seat, propelling it 100-200 feet above the aircraft. This gets the airman high enough to use a parachute even in a 'zero-zero ejection', when the aircraft has zero speed and zero altitude.

The system then fires an explosive catapult that deploys the drogue parachute, which slows the seat's speed (supersonic speeds are simply too fast to immediately deploy the main chute). When sensors determine the pilot is lower than 18,000 feet, the system releases the drogue chute and deploys the main parachute attached to the airman's harness. The system separates the airman from the seat, and the airman, along with a personal survival pack (including a raft), safely descends to the ground.

Amazingly, all this happens in a matter of seconds. It takes some people longer than that to get out of their easy chairs.

What is the sound barrier?

Breaking the sound barrier means exceeding the speed of sound at 40,000 feet, that's about 660 miles per hour

When Chuck Yeager broke the sound barrier with the Bell X-1 rocket plane in 1947, his mum wasn't mad. This was one case where breaking something was a good thing. The sound barrier is simply the point an object exceeds the speed of sound – a speed many scientists once considered impossible.

Sound is a travelling wave of pressure. A moving object pushes nearby air molecules, which push the molecules next to them, and so on. As a plane approaches the speed of sound, its pressure waves 'stack up' ahead of it to form a massive area of pressurised air, called a shock wave. Shock waves would shake old planes violently, creating an apparent 'barrier' to higher speeds.

You can hear shock waves as sonic booms. Sometimes they're even visible: the high pressure area can cause water vapour to condensate into liquid droplets, briefly forming a cloud around the plane.

The world's nuclea

From the 16th to 21st Centuries, submarines have inspired shock and awe in equal measure. HMS Astute is the latest and perhaps greatest example

First theorised in the 16th Century by Leonardo da Vinci and first deployed during the American Revolution, submarines have afforded navies the advantage of moving unseen, striking without warning and then disappearing without trace. Their effectiveness was restricted by only two things; the time they could remain submerged and the range of the weapons they carried. All this changed in 1954 and again the following year, with the world's first nuclear powered submarine (the USS Nautilus) and the first Submarine Launched Ballistic Missile (the Soviet R13). Today at least six nations include nuclear subs in their arsenal, although since the end of the Cold War, most carry conventional rather than nuclear weapons. The most expensive and, some would say, deadliest of these is the HMS Astute.

The Astute was the first UK-built submarine in almost 20 years, developed and constructed by BAE and launched on 8 June 2007. Astute contains around 50 per cent more firepower than the sub classes it replaces, totalling around 30 weapons systems including six torpedo tubes armed with Spearfish torpedoes and 36 Tomahawk Cruise missiles. Approximately 30 per cent larger than previous British attack submarines thanks to the bigger PWR2 Pressurised Water Reactor that powers it, safety is a primary consideration, especially while operating in the harshest environment on the planet, the deep ocean. It's a sobering thought that the 98-man crew will be living and working within a few metres of the core of a nuclear power plant more complex than a power station.

Astute's primary role is as an undersea hunter-killer, operating undetected hundreds of metres underwater while maintaining secure satellite communication. Its stealth credentials are enhanced by the 39,000 acoustic tiles that mask its sonar signature, as well as the 2076 Sonar System capable of tracking vessels across thousands of square miles of ocean. The Astute is capable of operating in isolation or as part of a taskforce with other naval vessels. It is expected to complete its 25-year life span without ever refuelling, patrolling submerged for 90 days at a time. In fact, the main limiting factor on its effectiveness is that it can only carry three months of food for the 98 strong all-male crew members onboard. With recent news that Britain's contingent of new Trident submarines are being reduced to three and not deployed until 2025, Astute class represents the immediate future of submarine warfare.

"Construction required over 1 million components, 7,000 design drawings, 10,000 separate engineering requirements and 100km of pipework"

WEIGHT 7,800 tons LENGTH 97m SPEED 29 knots
CREW 98 TIME TO BUILD 6 years 4 months

DID YOU KNOW? This 7,800 ton sub will make no more noise than a baby dolphin

deadliest
r submarine

Made in Britain
The vessel was built at BAE's submarine facility in Barrow

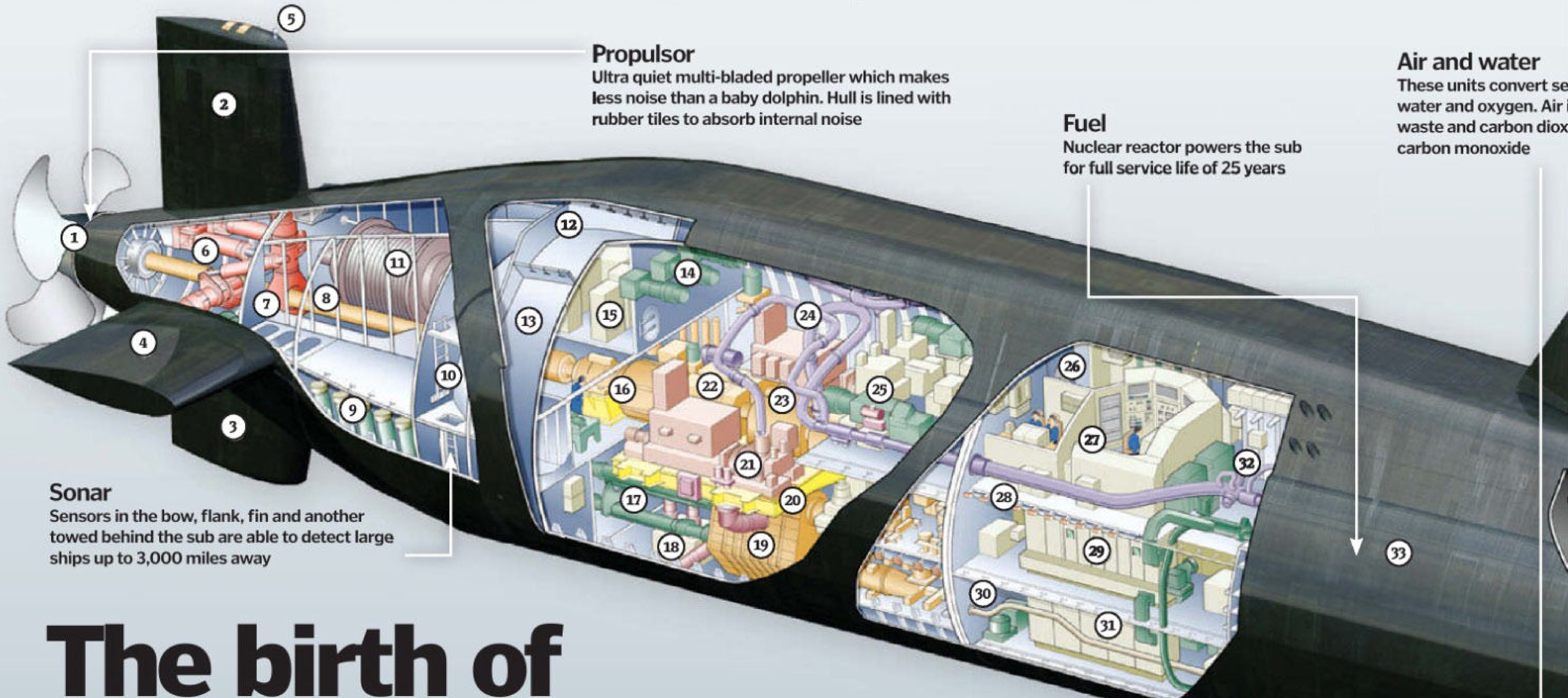
One of seven
HMS Astute is the first of seven Astute-class subs to replace the Swiftsure and Trafalgar-class

All images © BAE Systems

Team effort
Around 6,000 people were involved in the Astute's construction

On board HMS

Take a look beneath the hull of the world's most advance



The birth of the Astute

Astute was the first nuclear submarine to be designed entirely in a 3D Computer Aided Design environment

HMS Astute is the first in a program to design seven Astute-class subs to replace the Royal Navy's aging Swiftsure and Trafalgar-class. Three similar subs (Ambush, Artful and Audacious) have already been approved to follow.

Around 6,000 people were involved in Astute's construction at BAE's Devonshire Dock Hall in Barrow-in-Furness, the largest shipbuilding construction complex of its kind in Europe, covering an area of 25,000 square metres. Astute's construction required over 1 million components including 7,000 design drawings., 10,000 separate engineering requirements and 100km of pipework.

A number of technical challenges had to be overcome during the 17-year cycle from concept design to nuclear powered vessel. Not least of these was the fact that with space at an absolute premium, Astute's machinery and equipment is three times more densely packed than that of a surface warship.

Astute was the first nuclear submarine to be designed entirely in a 3D Computer Aided Design environment. With very little time or budget for designing a prototype in the usual manner, this system of 'virtual' prototyping harnessed the power of computer test and visualisation, along with continuous design and careful systems analysis. Some areas of the Astute, such as the command deck and forward engine room, were manufactured in modules, assembled in the workshop. They were then shipped to the Devonshire dock hall and carefully placed within the hull; an example of 'plug and play' construction that not only saves time but also minimised rework.

The structure of the sub is made up of a pressure hull – a perfect cylinder with rounded dome ends demonstrating that circularity is one of the keys to surviving deep ocean pressures. There are six sections between the end domes each containing different packages of equipment, and the hull sections are meticulously welded together in a process involving more than 2km of welding, all completed without a single defect and exhaustively examined for flaws using x-ray and ultra-sonic technology.

The reveal
Built at Europe's largest submarine dockyard, Astute first emerged to public gaze in 2007

1. HMS Astute
Nationality: British
Weight: 7,800 tons
Length: 97m
Speed: 29 knots

2. USS Alabama
Nationality: American
Weight: 18,750 tons
Length: 170 metres
Speed: 20 knots

3. Yuri Dolgoruki
Nationality: Russian
Weight: 24,000 tons
Length: 170 metres
Speed: 25 knots

DID YOU KNOW? *The HMS Astute can circumnavigate the world without surfacing*

S Astute

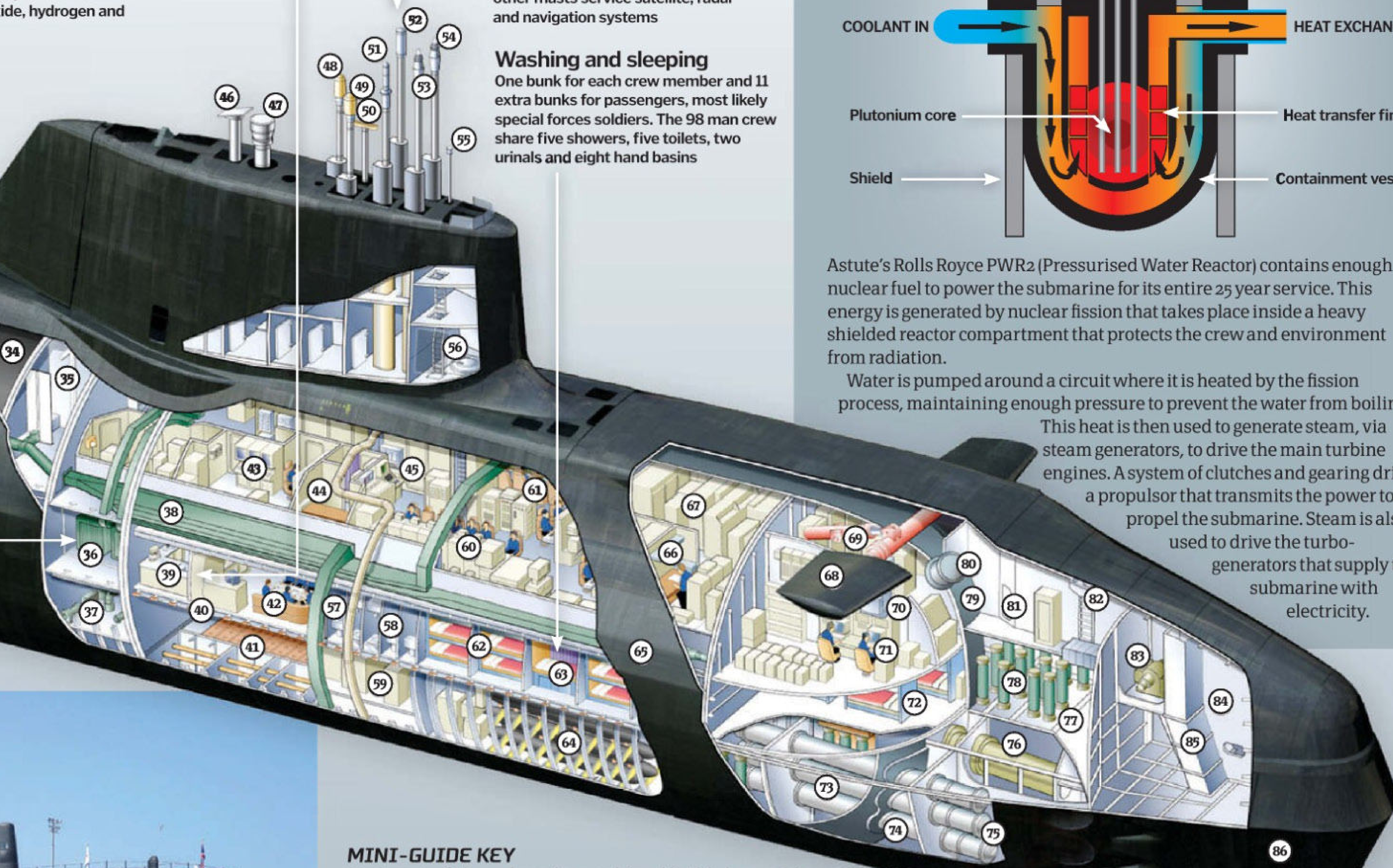
ed submarine

a water into fresh
is purified to remove
ide, hydrogen and

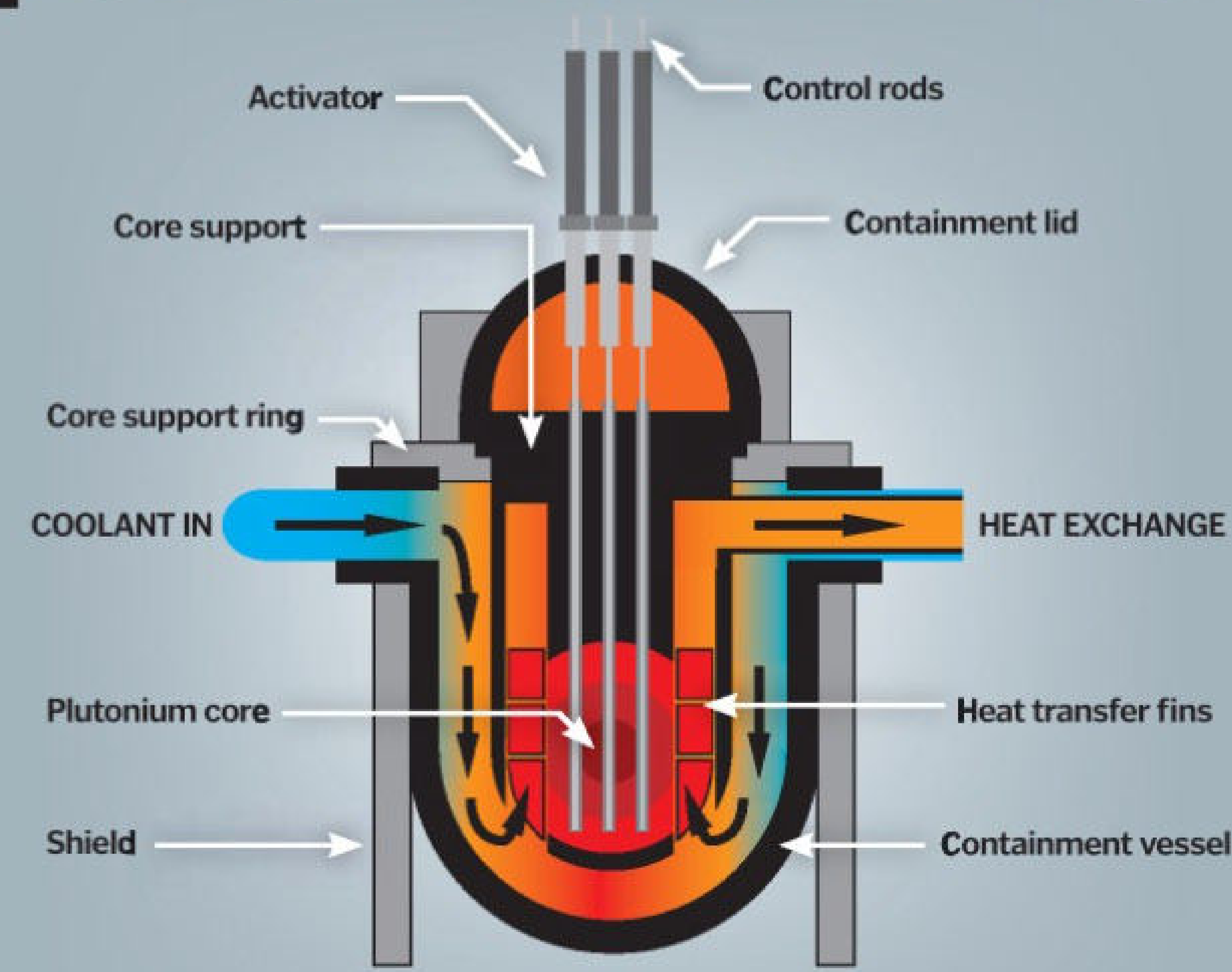
Galley
Five chefs provide a 24-hour service to the crew

Masts
Two masts carrying thermal imaging and low light cameras replace the periscope. Breaking the surface for less than three seconds is enough for a 360˚ view of the surroundings. Six other masts service satellite, radar and navigation systems

Washing and sleeping
One bunk for each crew member and 11 extra bunks for passengers, most likely special forces soldiers. The 98 man crew share five showers, five toilets, two urinals and eight hand basins



How does a reactor power a submarine?



Astute's Rolls Royce PWR2 (Pressurised Water Reactor) contains enough nuclear fuel to power the submarine for its entire 25 year service. This energy is generated by nuclear fission that takes place inside a heavy shielded reactor compartment that protects the crew and environment from radiation.

Water is pumped around a circuit where it is heated by the fission process, maintaining enough pressure to prevent the water from boiling. This heat is then used to generate steam, via steam generators, to drive the main turbine engines. A system of clutches and gearing drive a propulsor that transmits the power to propel the submarine. Steam is also used to drive the turbo-generators that supply the submarine with electricity.

MINI-GUIDE KEY

Each part of the submarine explained in this key guide

1 Propeller
2 Upper rudder segment
3 Lower rudder segment
4 Starboard hydroplane
5 Aft anchor light
6 Rudder and hydroplane hydraulic actuators
7 No. 4 main ballast tank
8 Propeller shaft
9 High pressure bottles
10 No. 3 main ballast tank
11 Towed array cable drum and winch
12 Main ballast vent system
13 Aft pressure dome
14 Air treatment units
15 Naval stores
16 Propeller shaft thrust block and bearing
17 Circulating water transfer pipes
18 Lubricating oil tank
19 Starboard condenser
20 Main machinery mounting raft
21 Turbo generators, port and starboard
22 Combining gearbox
23 Main turbines
24 Steam delivery ducting
25 Engine room
26 Watertight bulkhead
27 Manoeuvring room
28 Manoeuvring room isolated deck mounting
29 Switchboard room
30 Diesel generator room
31 Static converters
32 Main steam valve
33 Reactor section
34 Part of pressure hull
35 Forward airlock
36 Air handling compartment
37 Waste management equipment
38 Conditioned air ducting
39 Galley
40 Fwd section isolated deck mountings
41 Batteries
42 Junior ratings' mess
43 RESM office
44 Commanding officer's cabin
45 Port side communications office
46 Diesel exhaust mast
47 Snort induction mast
48 SHF/EHF (NEST) mast
49 CESM mast
50 AZL radar mast
51 Satcom mast
52 Integrated comms mast
53 Visual mast – starboard
54 Visual mast – port
55 Navigation mast
56 Bridge fin access
57 Junior ratings' bathroom
58 Senior ratings' bathroom
59 Battery switchroom
60 Control room consoles
61 Sonar operators' consoles
62 Senior ratings' bunks
63 Medical berth
64 Weapons stowage and handling compartment
65 Sonar array
66 Maintenance workshop
67 Sonar equipment room
68 Forward hydroplane
69 Hydroplane hydraulic actuator
70 Hydroplane hinge mounting
71 Ship's office
72 Junior ratings' berths
73 Torpedo tubes
74 Water transfer tank
75 Torpedo tube bow caps
76 Air turbine pump
77 No. 2 main ballast tank
78 High pressure air bottles
79 Forward pressure dome
80 Weapons embarkation hatch
81 Gemini craft stowage
82 Hinged fairlead
83 Anchor windlass
84 No. 1 main ballast tank
85 Anchor cable locker
86 Bow sonar

The sub that will rule the waves

Discover the awesome capabilities of the Royal Navy's latest supersub

When the first of the Astute-class subs finally enters full service it will not only be the Royal Navy's largest and most powerful nuclear attack submarines, but also the stealthiest.

Stealth is an important element of the submarine's operation because combined with advance sonar it enables the submarine to track, identify and neutralise an enemy before that vessel even knows the Astute is in the vicinity. Much of the equipment is shock mounted to prevent the transmission of sound and vibration into the surrounding ocean, and active vibration technology is also used with vibrating mounts tuned to a frequency effectively cancelling out the vibration of the equipment itself. There is also a multi-bladed propulsor housed at the rear and designed for near-silent running. The whole of the submarine casing is enveloped in a very dense rubber skin to reduce sound transmission into the ocean and also to diminish the submarine's own sonar profile. All this technology combines to make the submarine virtually invisible in the ocean.

In the cockpit itself, two Thales Optronics CM010 periscopes will ensure that Astute's commander never has to hunch over an optical periscope. Instead, the optronics masts are fitted with thermal imaging cameras, low light video and CCD TV sensors, replacing conventional line-of-sight systems to enable the Astute to first capture and then analyse any surface images. The masts are also non-hull penetrating, significantly reducing the risk of water leakage in the event of any damage the vessel may incur.

Astute is equipped with the Thales Sonar 2076, the world's most advanced sonar system, employing the processing power of 2,000 laptop computers to locate and identify other vessels that may be present across thousands of square miles of ocean. It is an integrated passive/active sonar that operates through hydrophones fitted to the bow, flanks and fin. However, details of Astute's counter measures are a closely guarded secret, in particular the exact thickness of the hull which could be an indicator of dive performance. What we do know is that it is manufactured from special grade submarine steel and coated in over 39,000 rubberised acoustic tiles to mask its sonar signature.

"Despite weighing over 7,800 tons, Astute displays a sonar profile equivalent to a baby dolphin"

Plug and play
Some areas were manufactured as modules then carefully placed within the hull

The hull
Despite being the first part to emerge, Astute's hull is its most closely guarded secret

5 TOP FACTS HMS ASTUTE

Slippery when wet

1 Despite weighing over 7,800 tons and measureing 97m in length, the Astute displays a sonar profile that is equivalent to a baby dolphin.

You are what you eat

2 On a ten week patrol, the crew of Astute would get through an average 18,000 sausages and 4,200 Weetabix for breakfast.

First in class

3 Since 1945 Barrow has built the first of class for every Royal Navy submarine as well as every submarine currently in service with the Navy.

Too many cooks?

4 A team of five chefs (one petty officer caterer, one leading chef and three chefs) provide 24 hour service to the crew.

No easy task

5 One of the most challenging engineering projects in the UK, building Astute has been described as "more complex than the space shuttle".

DID YOU KNOW? *If it was positioned in the English Channel the Astute could hit targets in North Africa*

Weapons and missiles

When it comes to offensive capability, Astute marks a significant leap over the submarine classes it replaces. With a total of 38 Spearfish torpedoes and Tomahawk missiles – more than any previous RN submarine – and six 21-inch (533 mm) torpedo tubes, Astute has the capability to accurately engage targets over 1,000 miles away while remaining undetected.

Powered by a high-performance thermal engine, Spearfish has an analogue homing system and communicates with the launch submarine through a wire-guidance link.

Meanwhile the Tomahawk Block IV Land Attack Missile (LAM) is the latest version of McDonnell Douglas's medium-to-long range cruise missiles, designed to operate at low attitude and launch while the Astute is fully submerged. It is capable of delivering pin-point strikes 2,000km from the coast.

As far as defensive capabilities are concerned, Astute is armed with Boeing UGM-84 Harpoon anti-ship missiles. This short range turbo-fan propelled missile carries a single warhead and is designed for surface-to-surface strikes at a range of around 140km.

Spearfish torpedoes
Weighing nearly two tons, the Spearfish is a serious weapon

Tomahawk Block IV Land Attack Missile (LAM)
The UK is the only nation, other than the USA, to have the Tomahawk Block IV

Learn more

For more information about HMS Astute visit **www.naval-technology.com/projects/astute/** where you can find more facts about this formidable addition to the Royal Navy fleet.

View from the bridge

An interview with Astute's commander

Andy Coles, OBE is 47 and commanding Astute will mark the pinnacle of a 30-year Navy career that began as a radar operator. He told us what he's most looking forward to from the experience.

"HMS Astute is a keenly awaited and extremely capable submarine which will prove to be a very potent weapon for the Royal Navy for the next 25 years. She represents a massive increase in capability over previous classes and I am really looking forward to putting the submarine through her paces during sea trials. Her offensive capability has been greatly enhanced; while she carries the same Spearfish torpedoes and Tomahawk Cruise missiles as previous classes, Astute's payload is significantly increased and a return to six torpedo tubes greatly enhances the flexibility. Astute is also the first submarine to have non hull-penetrating optronics masts, making it much easier for me to see what is happening on the surface as the picture is displayed on several large screens in the Control Room, the submarine's operations centre. One of the significant design changes is to enable the submarine to operate with Special Forces and I am looking forward to proving that part of the sea trials.

"Of course, none of this technology would work if it wasn't for the people. Astute has been designed to reduce the manning at sea. I have a highly trained crew; from the officers, senior ratings and junior ratings who operate the submarine to marine engineers (propulsion, mechanical and electrical systems), weapon engineers to ensure the weapon and electrical systems are at maximum readiness and warfare specialists to operate them. Finally, I have a team of logisticians who look after everything from storing the submarine to providing three meals a day for over a hundred submariners."

This month in **Space**

Ever dreamt of booking a ticket to space on a commercial space craft? Thanks to Richard Branson's SpaceShipTwo this may soon be a possibility. Turn the page to take a look at how this sub-orbital craft will take passengers to the edge of space and back again.

SPACE

Inside the Sun

The giant star that keeps us all alive…

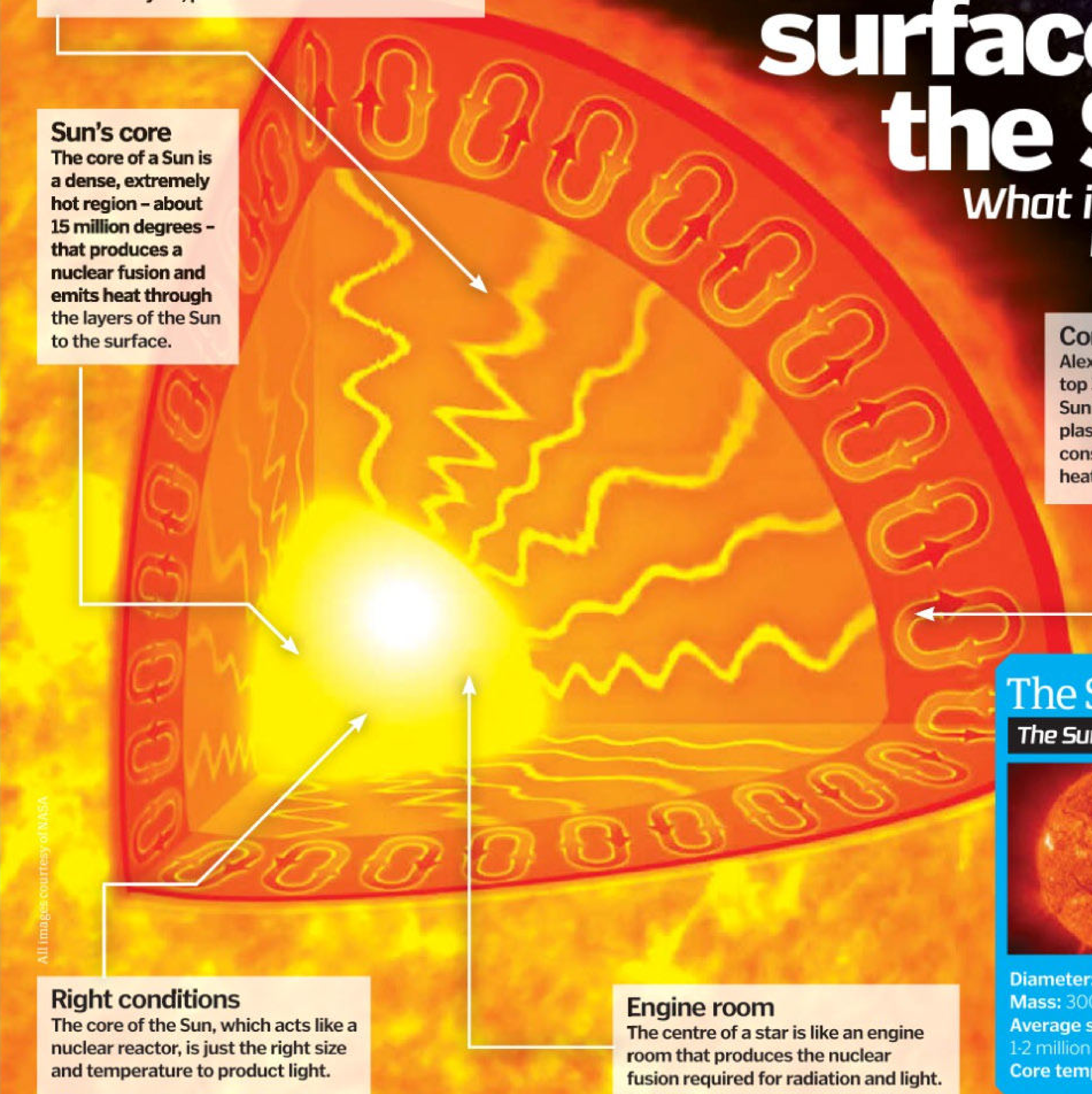
A celestial wonder, the Sun is a massive star that formed from a massive gravitational collapse when space dust and gas from a nebula collided, forming into an orb that is 100 times bigger and weighs over 300,000 times that of planet Earth. Made up of 70 per cent hydrogen and about 28 per cent helium (plus other gases), the Sun is the centre of our solar system and the largest celestial body anywhere near us.

"The surface of the Sun is a dense layer of plasma at a temperature of 5,800 degrees kelvin that is continually in motion through the action of convective motions driven by heating from below," says David Alexander, a professor of physics and astronomy at Rice University. "These convective motions show up as a distribution of what are called granulation cells about 1,000km across and which appear across the whole solar surface."

Essentially, this constant motion of high-temperature causes a nuclear reaction. In the core of the Sun, hydrogen turns into helium and causes a fusion – which moves to the surface of the Sun, escaping into space as electromagnetic radiation, a blinding light, and incredible levels of solar heat. In fact, the core of the Sun is actually hotter than the surface, but when the fusion escapes from the surface, the temperature rises to over 1-2 million degrees. Alexander explained that astronomers do not fully understand why the Sun's atmosphere is so hot, but think it has something to do with a magnetic field.

Beneath the surface of the Sun

What is the Sun made of?



Radiative zone
The first 500,000k of the Sun is a radioactive layer that transfers energy from the core, mostly toward the outer layers, passed from atom to atom.

Sun's core
The core of a Sun is a dense, extremely hot region – about 15 million degrees – that produces a nuclear fusion and emits heat through the layers of the Sun to the surface.

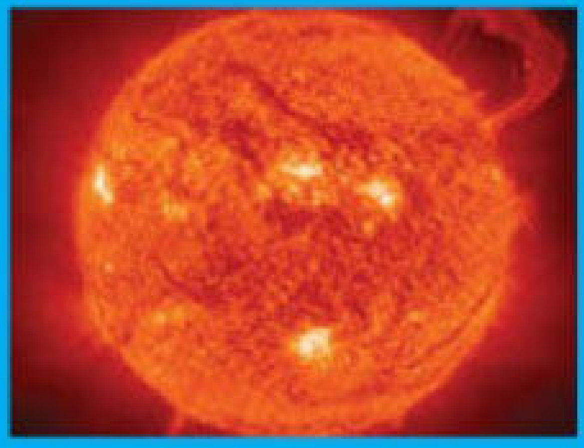
Convective zone
Alexander says the top 30 per cent of the Sun is a layer of hot plasma that is constantly in motion, heated from below.

Right conditions
The core of the Sun, which acts like a nuclear reactor, is just the right size and temperature to product light.

Engine room
The centre of a star is like an engine room that produces the nuclear fusion required for radiation and light.

The Statistics

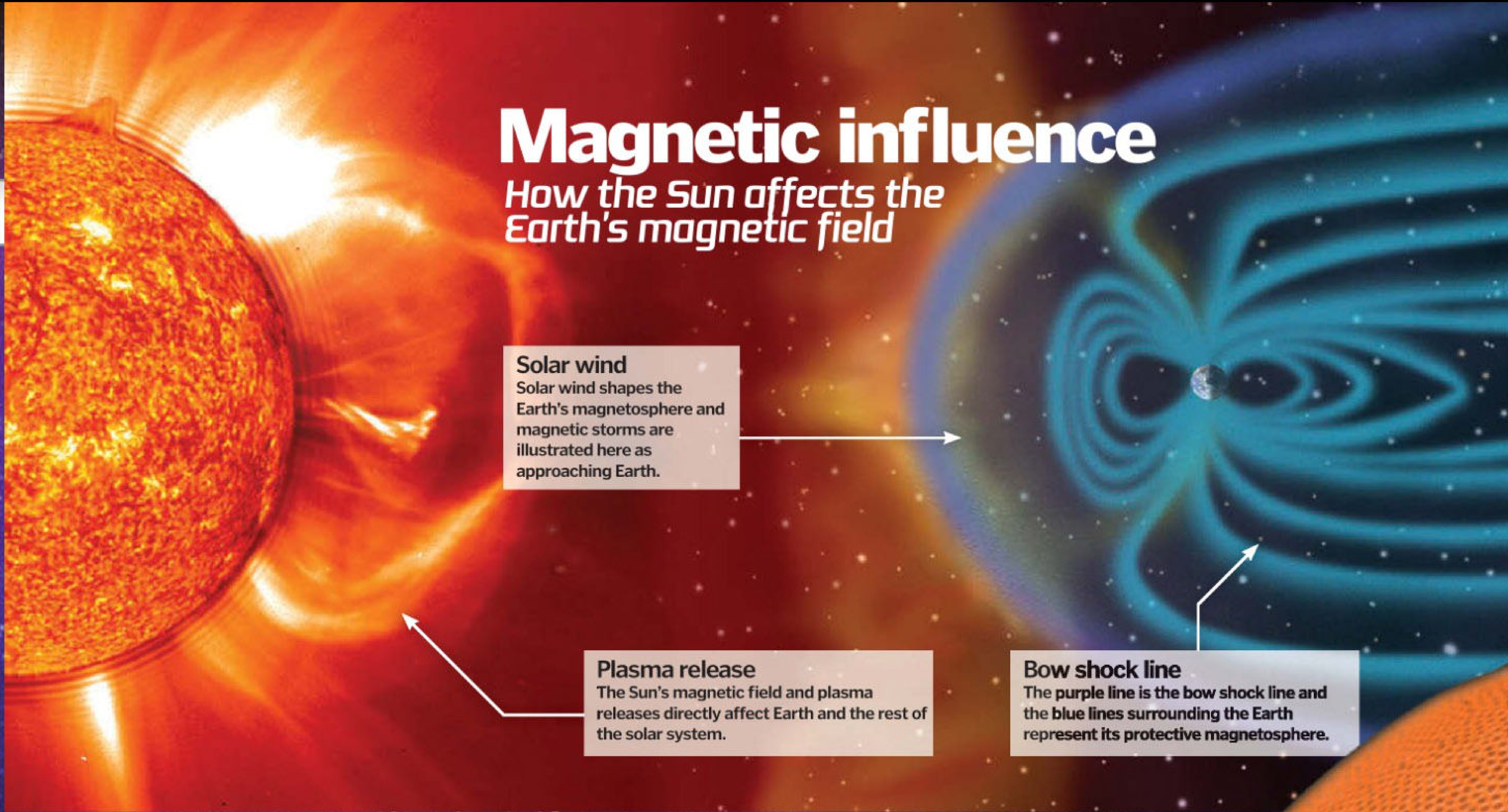
The Sun



Diameter: 100 times Earth
Mass: 300,000 times Earth
Average surface temp: 1-2 million degrees
Core temp: 15 million degrees

Magnetic influence

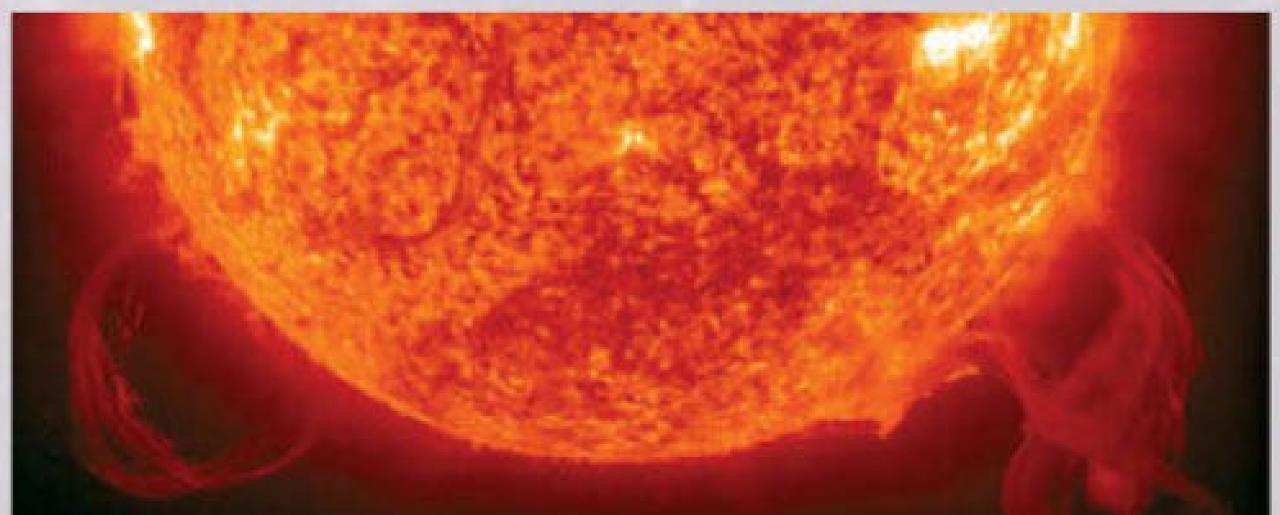
How the Sun affects the Earth's magnetic field



What is a solar flare?

A solar flare is like a massive explosion, just one that happens to be several million degrees in temperature…

"A solar flare is a rapid release of energy in the solar atmosphere (mostly the chromosphere and corona) resulting in localised heating of plasma to tens of millions of degrees, acceleration of electrons and protons to high energies, some to near the speed of light, and expulsion of material into space," says Alexander. "These electromagnetic disturbances here on Earth pose potential dangers for Earth-orbiting satellites, space-walking astronauts, crews on high-altitude spacecraft, and power grids on Earth."



Solar flares can cause geomagnetic storms on the Sun, including shock waves and plasma expulsions

Solar eclipses

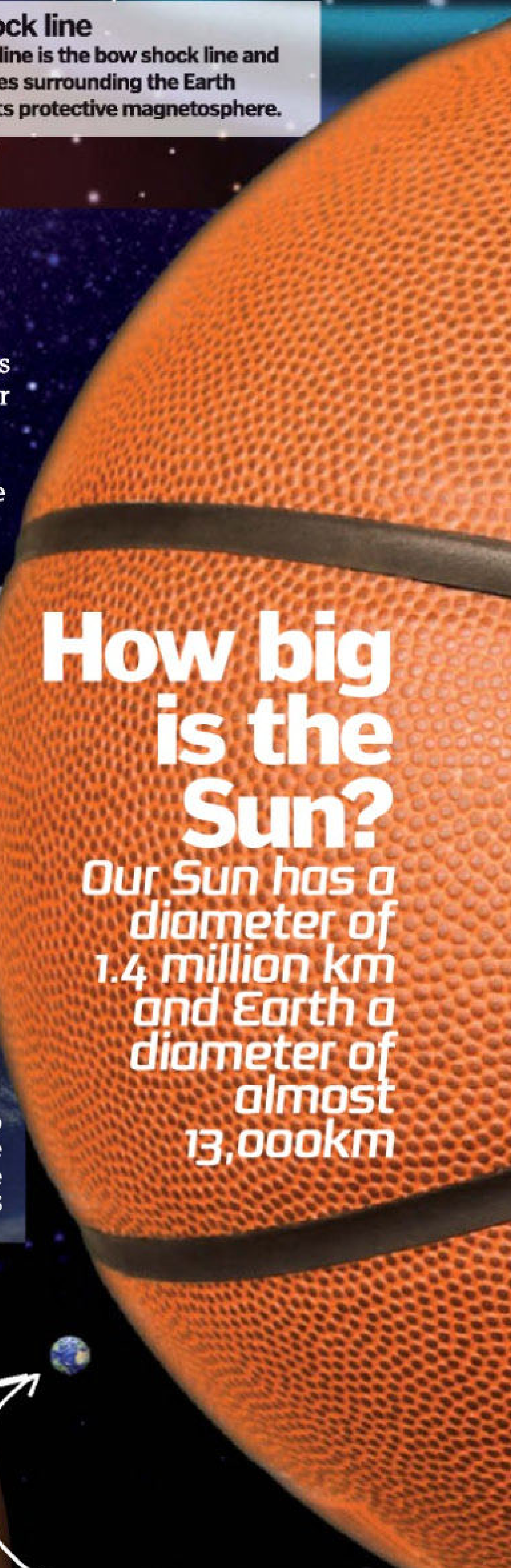
When the moon blocks out the Sun

A solar eclipse is a unique phenomena where the moon passes directly into a line between the Earth and the Sun, partially or completely blocking our view of the Sun. The Sun is blocked according to the relative orbits of each celestial body. There are two kinds of eclipses: one where the moon orbit shows the outer edge of the Sun, or where the moon lines up perfectly and the Sun is blocked completely from view.

Sometimes, the orbits of the Earth and Sun line up perfectly so that the Sun is blocked (eclipsed) by the moon, shown here with a shadow cast from the eclipse, taken from the ISS

How big is the Sun?

Our Sun has a diameter of 1.4 million km and Earth a diameter of almost 13,000km



If the Sun were the size of a basketball, Earth would be a little dot no more than 2.2mm

What is a sunspot?

Far below the surface of the Sun, near the core, a strong magnetic field – which is the force created by the Sun's high core temperature and nuclear fusion – emits a sunspot, which looks like a black dot on the Sun because it is about 1,000 degrees cooler than the surface temperature. Interestingly, a sunspot also causes the magnetic field required for solar flares and a CME. "A CME (coronal mass ejection) is an additional phenomenon which is separate but often accompanies the largest flares," says Alexander, explaining how plasma from a CME ejects from the Sun at over 1 million miles per hour.

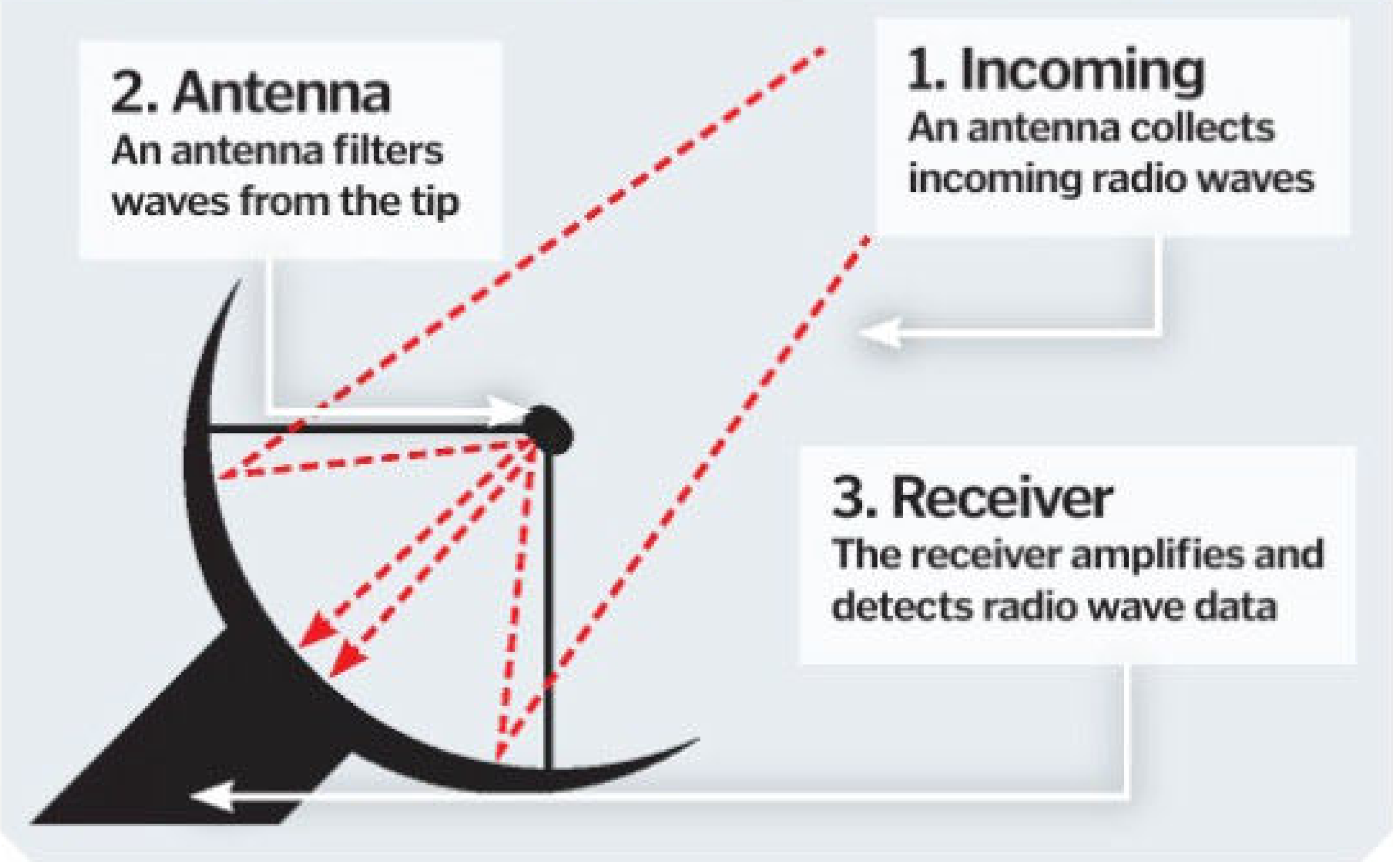
Radio telescopes explained

What frequency is a quasar?

Some objects in space are viewable with the naked eye – at least with the help of a powerful optical telescope. Other anomalies such as quasars (the most powerful source of energy in the universe – a kind of star galaxy) and pulsars (spherically shaped neutron stars) require the use of a radio telescope, which sends powerful energy frequencies into space using antennas. A radio telescope measures the intensity of radio frequencies.

"By studying the intensity of radio frequencies, astronomers can monitor the conditions of space," says Dr Seth Shostak, a senior astronomer at the SETI Institute. "Radio waves are not hindered by gas and dust between stars, so you can 'look' straight through a galaxy to the other side. Quasars were found because of radio telescopes."

According to Dr Shostak, a radio telescope uses a very low-noise amplifier that collects radio waves, themselves collected using massive antennas. The signal passes through the antenna, spreads through a filtering system, and breaks into thousands of frequency channels – a bit like a Doppler satellite that measures the speed of frequencies.



What are Saturn's rings made of… and why are they there at all?

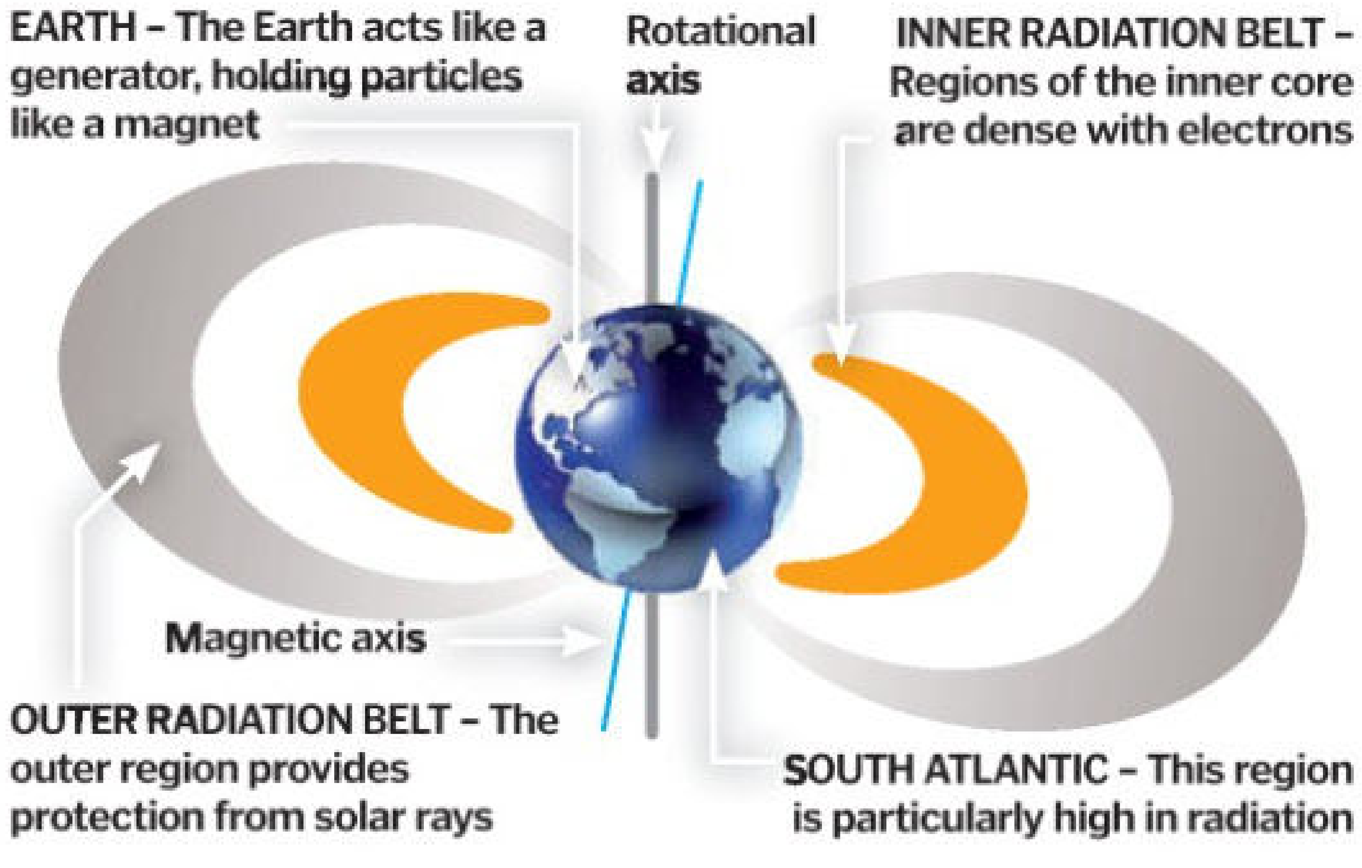
Why does Saturn have rings but other planets do not? The answer has to do with something called the Roche lobe, named after a French astronomer. It seems when a planet orbits around a star (eg our Sun) and that planet has its own orbiting objects (eg a moon), a gravitational pull occurs between the objects. Around Earth, orbiting rocks formed into the moon. On Saturn, the rocks never coalesced and are still orbiting.

Interestingly, the rings are only a few miles in thickness because of the highly localised effects from the Roche lobe. Dr Steve Maran, a noted astronomer, says Galileo was the first to discover the rings, but could not explain them. Today, viewing angles from the Hubble Space Telescope reveal an enormous region extending widely around the planet. There's also one distinct outer ring, which Maran attributes to geysers emitting from the icy southern polar region on Saturn, leaving a more distinct trail.

"The rings are only a few miles in thickness"

Van Allen radiation belt explained

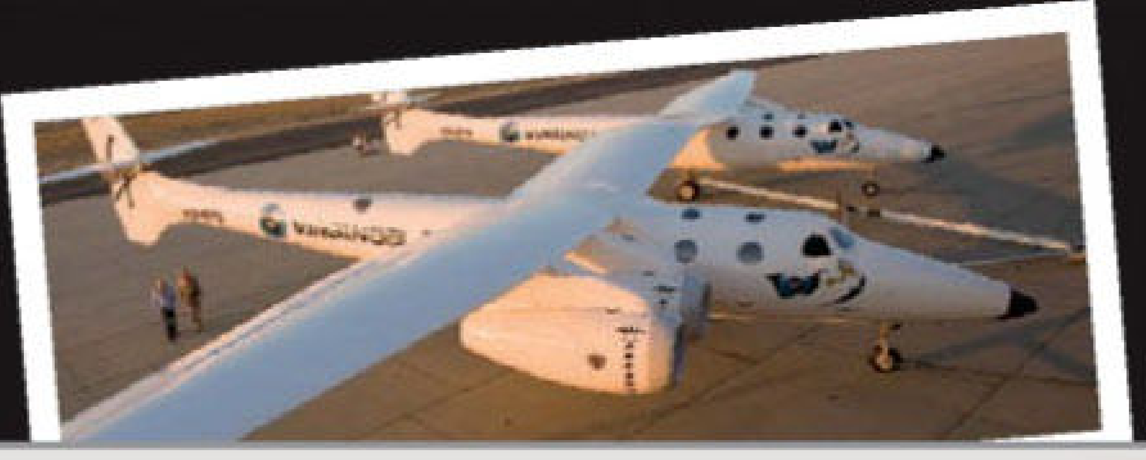
Particles around the Earth, but why?



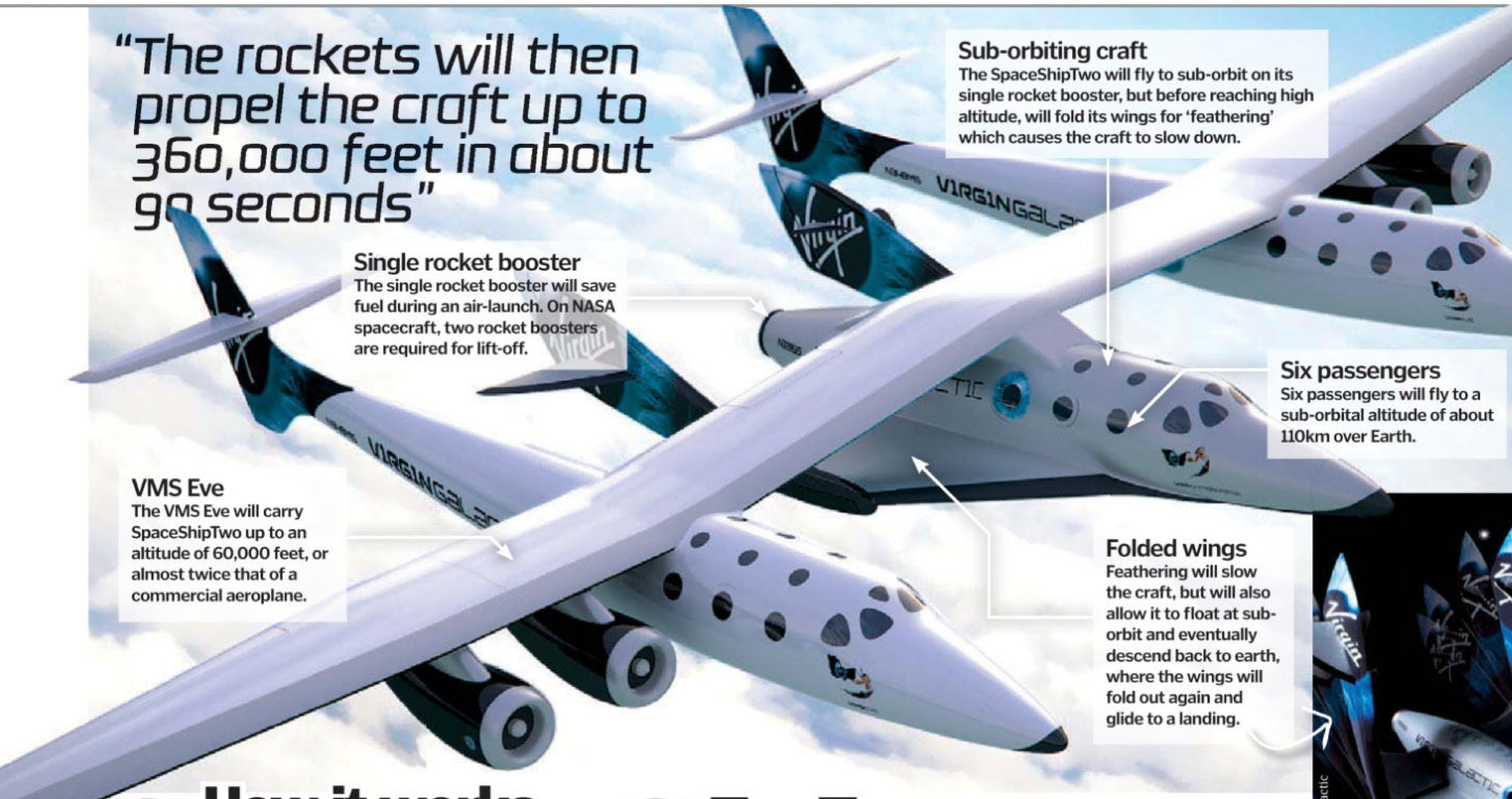
Microscopic particles – mostly electrons and protons – are assembled in a region about 70,000km from Earth's surface. But why does it exist?

The Van Allen radiation belt is named after James Van Allen, a NASA scientist who discovered it 50 years ago, but modern scientists refer to it as the magnetosphere because it's not a round belt – it's a region around Earth. According to Dr Steve Maran, astronomer and author, the magnetosphere is caused by a constant outstreaming of solar winds held in place by Earth's magnetic field (unlike other planets, Earth has a molten iron core that acts like a generator or motor). "At first, scientists thought the discovery showed how much we don't know about space," says Maran. "Now we know that the magnetosphere is responsible for Earth retaining most of its water and shields us from solar rays and planetary disturbances."

HEIGHT **4.5m tail** TOTAL WINGSPAN 42.7m
LENGTH 18.3m MAX SPEED **Mach 3.5**



DID YOU KNOW? *Its predecessor, SpaceShipOne, now hangs in the National Air and Space Museum, Washington DC*



All images © Virgin Galactic

How it works SpaceShipTwo

This second-generation spacecraft will fly 4,000km/h at 110km over Earth

Imagine flying 110 kilometres (360,000 miles) over the Earth, soaring across the Pacific Ocean at 4,000km/h, seeing entire continents, and reaching a sub-orbital altitude that only astronauts – and a handful of millionaires – have seen.

In the Virgin Galactic SpaceShipTwo, designed by Burt Rutan and Scaled Composites, commercial space flight will become routine – like catching a flight from Vienna to New York. The spacecraft, currently being built in California and almost ready for its first test flight, is made of a carbon-composite material and uses a rocket powered by nitrous oxide that will propel the craft at 4,000 kilometres per hour. In fact, this is the most important difference between SpaceShipTwo (which uses a single rocket and consumes less fuel) and the Space Shuttle (which uses two rockets – and more fuel).

To launch the SpaceShipTwo into space, Virgin Galactic will use a mothership launch vehicle called the Virgin Mothership (VMS) Eve that carries the spacecraft to about 50,000 feet, or several thousand feet above the typical altitude for aeroplanes. The rockets will then propel the craft up to 360,000 feet in about 90 seconds, or three times the speed of sound. SpaceShipTwo will carry six lucky passengers at a time.

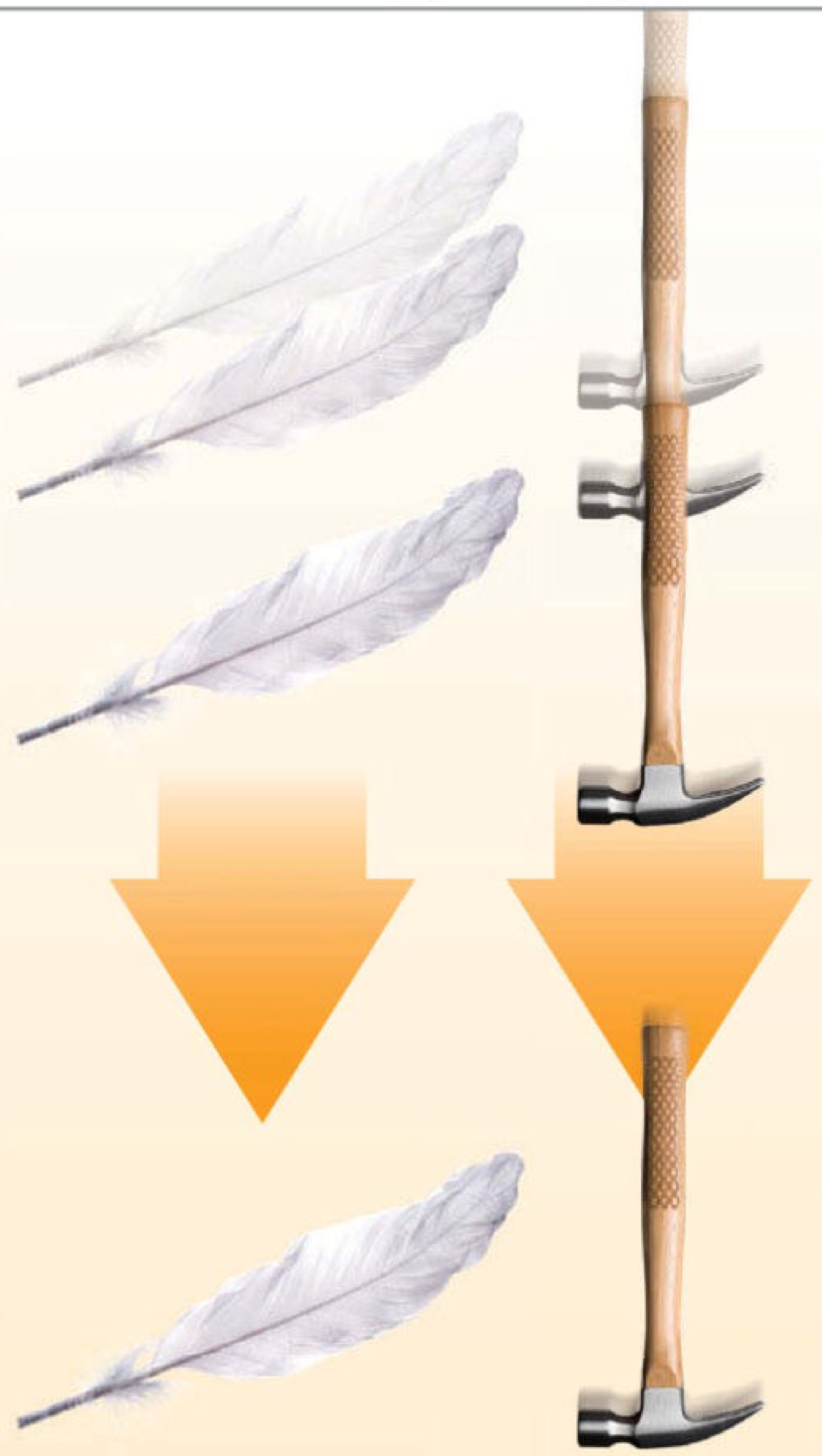
Just before reaching maximum altitude, the spacecraft will use a rather unique feathering technique. The wings of SpaceShipTwo will fold up and ultimately slow the aircraft which will then slowly descend to Earth's atmosphere. During re-entry, at approximately 60,000 feet, SpaceShipTwo will fold its wings back into position automatically, and glide back to dry land without using any more fuel or rocket boosts. Combined, this air-launch with the VMS Eve, assisted breaking (which uses the gravitational pull of the Earth), and free-fall descent use a limited amount of fuel – about as much as a commercial flight.

What a ride!
SpaceShipTwo will travel at three times the speed of sound

The key to how SpaceShipTwo works is the single-rocket booster, which would normally not be enough to launch the vehicle into space. Most NASA spacecraft use two solid-rocket boosters. Instead, the Eve launch vehicle will carry SpaceShipTwo into high altitude. Mission abort for most spacecraft is highly expensive, because the rocket fuel is consumed at launch regardless of whether the craft reaches orbit. With SpaceShipTwo, during the air-launch at high-altitude, the rocket boost can be shut down at any time – say, because of a mechanical problem or electrical failure – and aborted so that the craft can re-enter the Earth's atmosphere and glide back to land.

"Less fuel, and indeed clean fuel, all add up to a space launch system which will be completely unprecedented in its low environmental impact compared with current space flight," explains Sir Richard Branson, who is funding the spacecraft construction for Scaled Composites, speaking in a press release. "The spaceship's carbon footprint for each of its passengers and crew will be around a quarter of that for a simple return trip from London to New York."

Virgin Galactic says the SpaceShipTwo rocket testing will resume this autumn, with a planned first launch in late 2009 or early 2010.



What is

Surprisingly weak yet mysteriously powerful, gravity is the super glue of the universe

Everything in the universe is made of matter – the cosmic 'stuff' of creation. Mass is a measurement of the amount of matter contained in any object, from planets to protons. The Earth, for example, has a mass of 5.9742×10^{24} kilograms, while the mass of a single proton is 1.67262158 × 10-27 kilograms.

When we think of gravity, we usually think of the gravitational force exerted by massive (literally) celestial bodies like the Earth, the Moon or the Sun. But the truth is that any object of any mass – even a sub-atomic particle – exerts a gravitational pull on nearby objects.

Sir Isaac Newton proved that objects of greater mass exert a stronger gravitational force. That's why we typically talk about gravity in reference to planets and not protons. But the shocking truth about gravity is that even a colossal hunk of rock like the Earth exerts an exceptionally puny pull. An infant, in fact, can defeat the combined gravitational pull of every single atom on the planet by lifting a wooden block off the floor.

That's what makes Newton's discoveries so amazing, even today. Gravity – this wimp of a force – is somehow powerful enough to pull the moon into orbit and keep the Earth cruising in a perfect elliptical path around the Sun. Without the constant tug of gravity, planets would crumble into dust and stars would collapse.

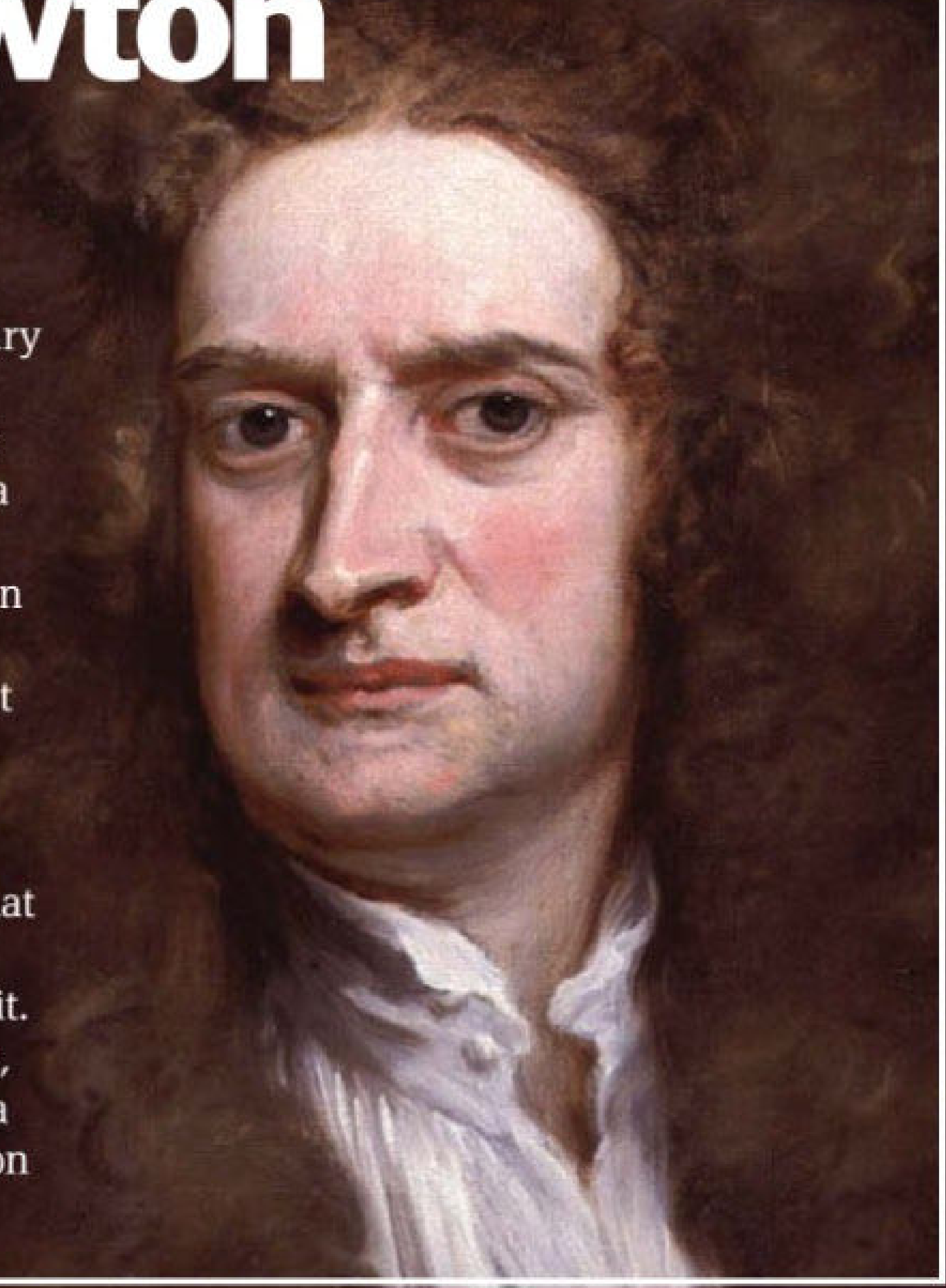
Gravity is also responsible for giving objects weight. But don't confuse weight with mass. While mass is a measurement of the amount of matter in an object, weight is the downward force exerted by all of that matter in a gravitational field. In the zero-gravity vacuum of space, objects are weightless, but they still have mass.

On the surface of the Earth, where the force of gravity is essentially constant, we consider mass and weight to be equal. But that same object – with the same mass – will weigh 17 per cent less on the Moon, where the gravitational pull is weaker. On Jupiter – not the best place to start a diet – that same object will weigh 213 per cent more.

Falling force

Legend has it that Galileo famously disproved Aristotle by dropping two cannonballs of different mass from the top of the Tower of Pisa and showing that they land simultaneously. In 1971, astronaut Dave Scott dropped a feather and a hammer on the moon, proving that all objects fall at the same rate in a vacuum.

Issac Newton



Sir Isaac Newton was born in 1642, the same year that Galileo died. While Galileo proved that objects of different masses fell at the same rate, it wasn't until Newton published his revolutionary Principia Mathematica – the most influential physics text of all time – that this mysterious force was finally given a name: gravity.

Newton's Universal Law of Gravitation was the first to explain gravity in clear, mathematical terms. It was also the first truly 'unified' theory, explaining both earthly and heavenly mechanics. To readers of his day, it would have been completely inconceivable to imagine that the same force that pulls apples from trees could also coax the moon into orbit.

Over 300 years after their publication, Newton's elegant formulas still played a vital role in putting humans on the moon for the first time.

5 TOP FACTS GRAVITY

Black hole
1 A black hole's gravitational pull is so strong that even light can't escape from what's known as its 'event horizon', an invisible boundary around it.

Mighty moon
2 The moon's low gravity means objects weigh one sixth of their Earth weight. A strong man could lift a small car on the moon!

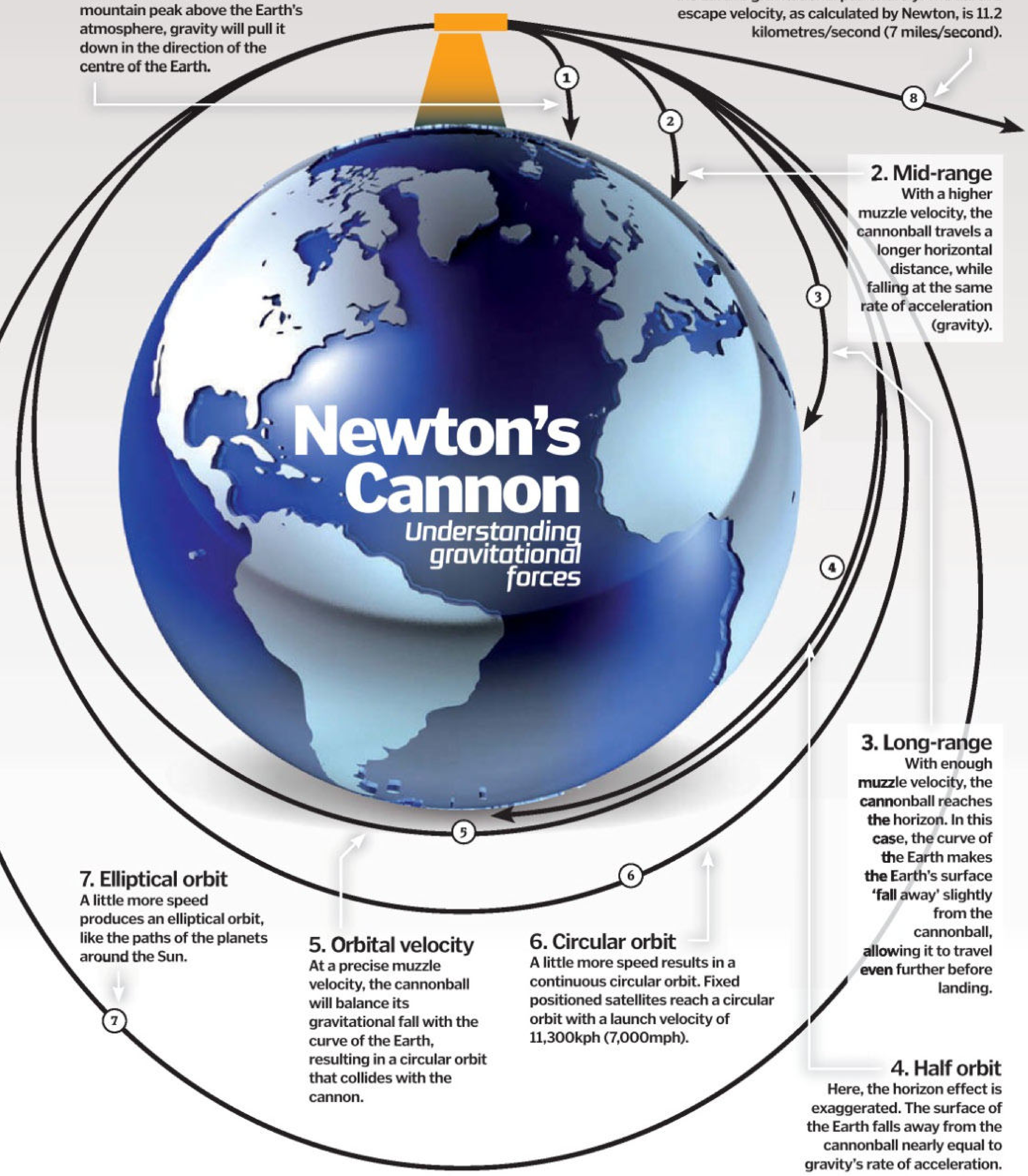
Escape velocity
3 Deimos, a moon of Mars, has such low gravity that if you jumped, you'd easily achieve escape velocity and send yourself into space.

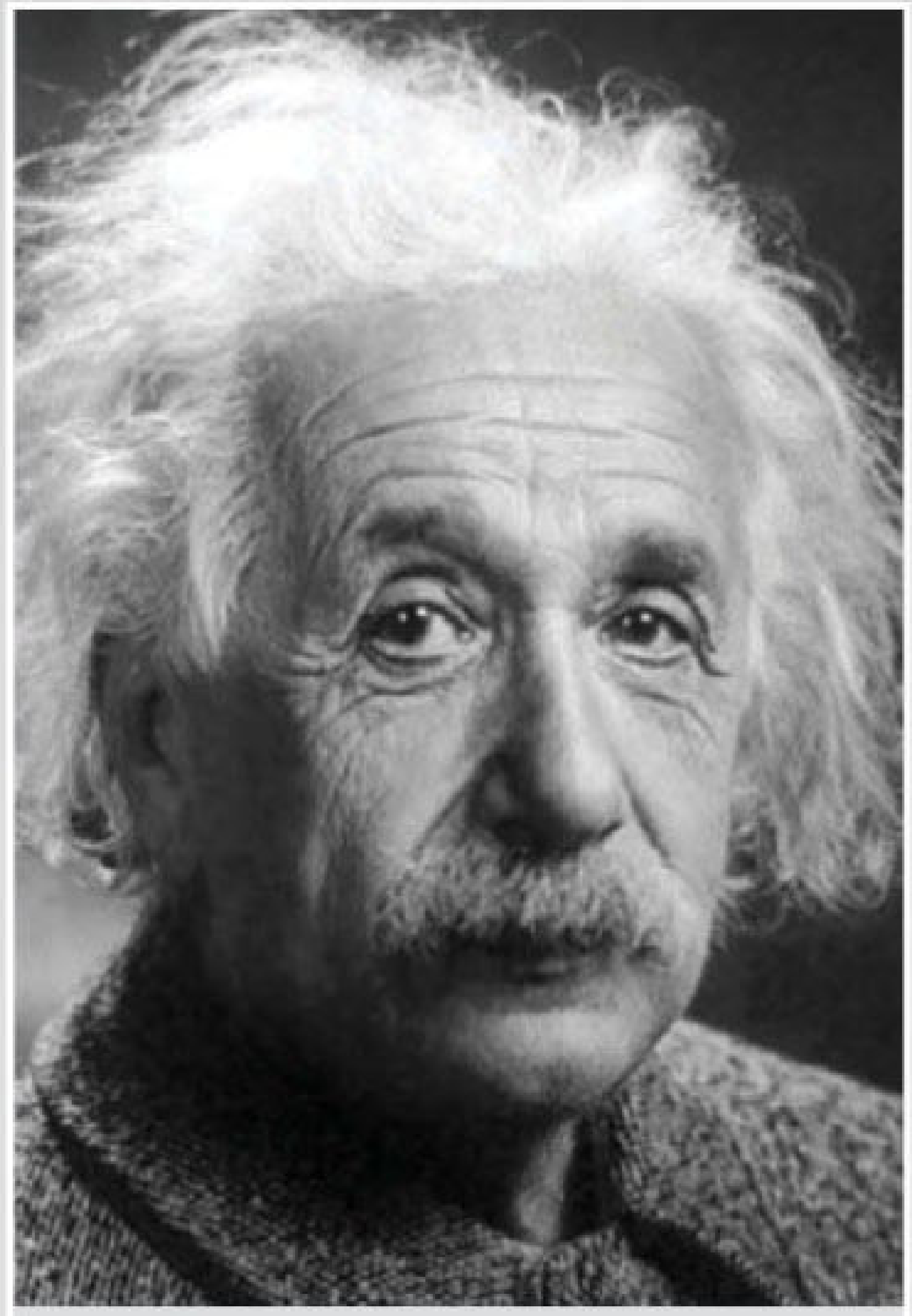
Gravity and fitness
4 Prolonged exposure to zero gravity poses health risk for astronauts, including bone loss, muscle atrophy and even immune problems.

Pulling power
5 Size and mass effect gravity: Uranus has 14.5 times the mass of Earth but because of its size, it only has around 90 per cent of Earth's gravity.

DID YOU KNOW? Albert Einstein won the Nobel Prize for Physics in 1921

s gravity?





Albert Einstein

While Newton was able to mathematically prove the existence of gravity, he had no idea where it came from or how it actually worked. In the Newtonian world view, gravity was a constant, independent force that acted instantaneously. If the Sun were to disappear, Newton argued, then the planets would immediately spin off into the void.

In 1905, a young and unknown Albert Einstein postulated that light travelled at a discrete speed limit through the vacuum of space. Since nothing can travel faster than light, the force of gravity cannot act instantaneously. If the Sun disappeared, it would take over eight minutes for the loss of gravity to be felt by Earth.

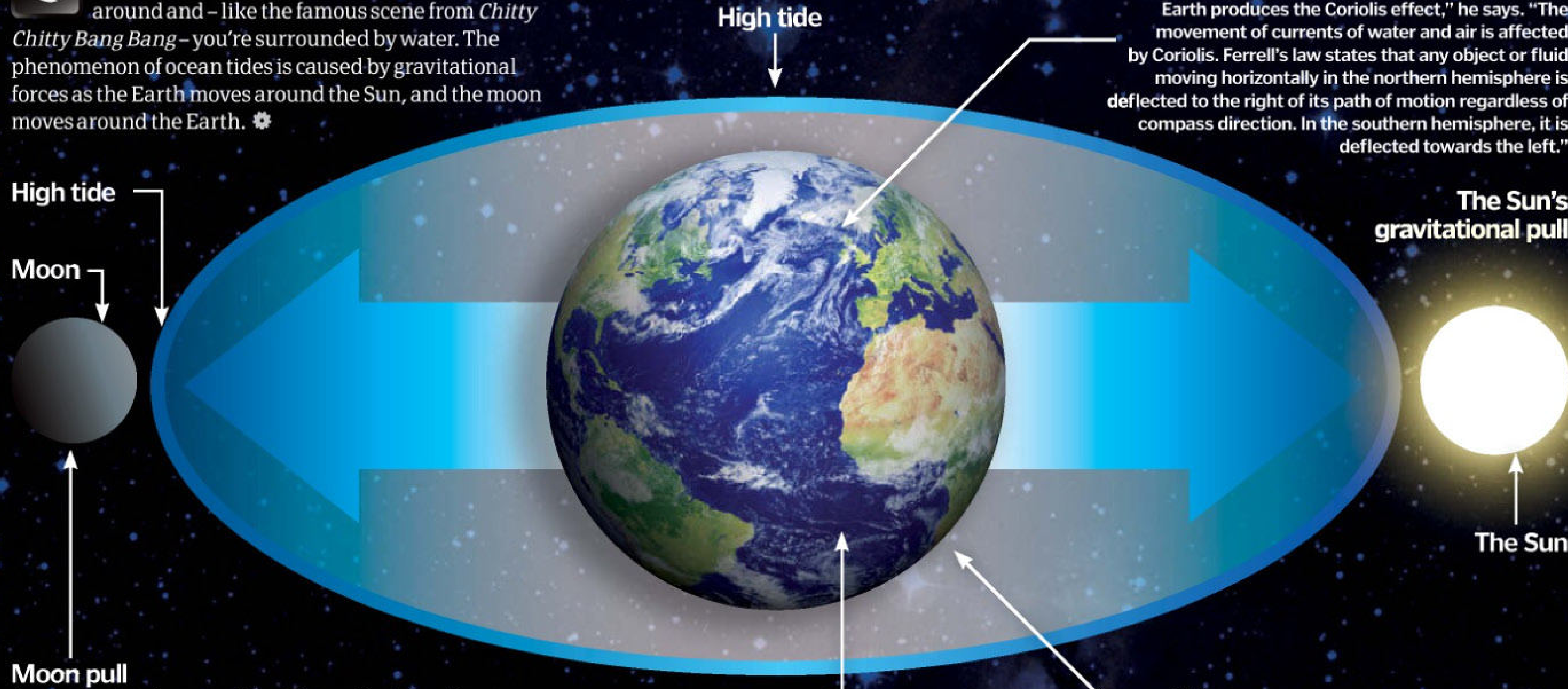
But Einstein's most mind-boggling gravitational insight came in 1916 with the General Theory of Relativity. In his radical view of the universe, the three dimensions of space are merged with a fourth dimension of time and represented as a flexible, two-dimensional 'space-time' fabric.

According to Einstein, objects of great mass act like bowling balls on a trampoline, bending and warping the space-time fabric. If a smaller object rolls too close one of these bowling balls, it will be drawn toward it. Gravity is not some mysterious independent force, but the result of the collective wrinkles in the fabric of the universe.

How ocean tides work

Gravitational forces tip ocean waters like a bathtub

You're sitting on a beach, cooking a barbecue with the family. The Sun sets in the distance. You look around and – like the famous scene from *Chitty Chitty Bang Bang* – you're surrounded by water. The phenomenon of ocean tides is caused by gravitational forces as the Earth moves around the Sun, and the moon moves around the Earth.



Adaptive optics recreate an image

Reassembling a twinkling star

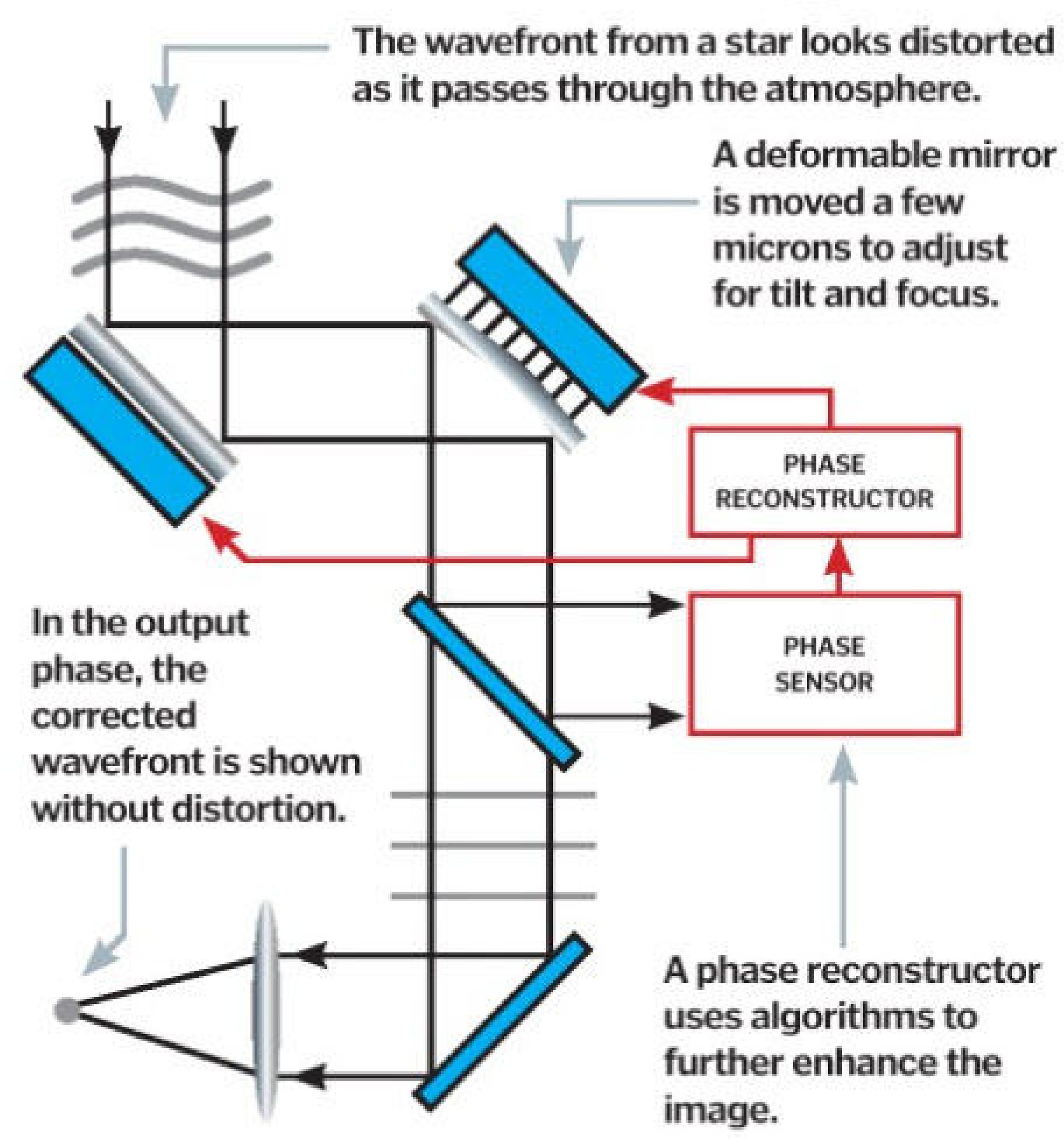
Adaptive optics is a fascinating field – this technology is used in telescopes and can reconstruct an image so that it matches how the object looks in space, without the distortions from the Earth's atmosphere. It's the same technology now being used by optometrists to determine which glasses you might need to wear.

When astronomers study a star, the light is emitted in a spherical shape called a wavefront. As the wavefront passes through the atmosphere, the spheres are distorted in the same way that a distant car is distorted by the heat on a paved road. Some parts of the star are tilted – like the slanted image you might see on a wall when the Sun shines through a window. Other parts are out of focus.

The distorted image is called the input phase, or wavefront phase. Initially, a tilt mirror captures the wavefront, which measures the complex tilt of the image. Next, a deformable mirror is used to adjust the image. This mirror acts like one in a hall of mirrors, except the mirror can be moved a few microns to flatten the image. The image passes through the deformable mirror multiple times, and each time a phase reconstructor – a series of complex algorithms – smooths the image.

In a last step, the adjusted image enters the output phase, which shows the adjusted image without the distortions of tilt and focus. "Adaptive optics cancel out the effects of the atmosphere as well as the imperfections of the telescope," says Stuart Shacklan, a group supervisor of the high contrast imaging group in the optics section at Jet Propulsion Laboratory, a research arm of NASA.

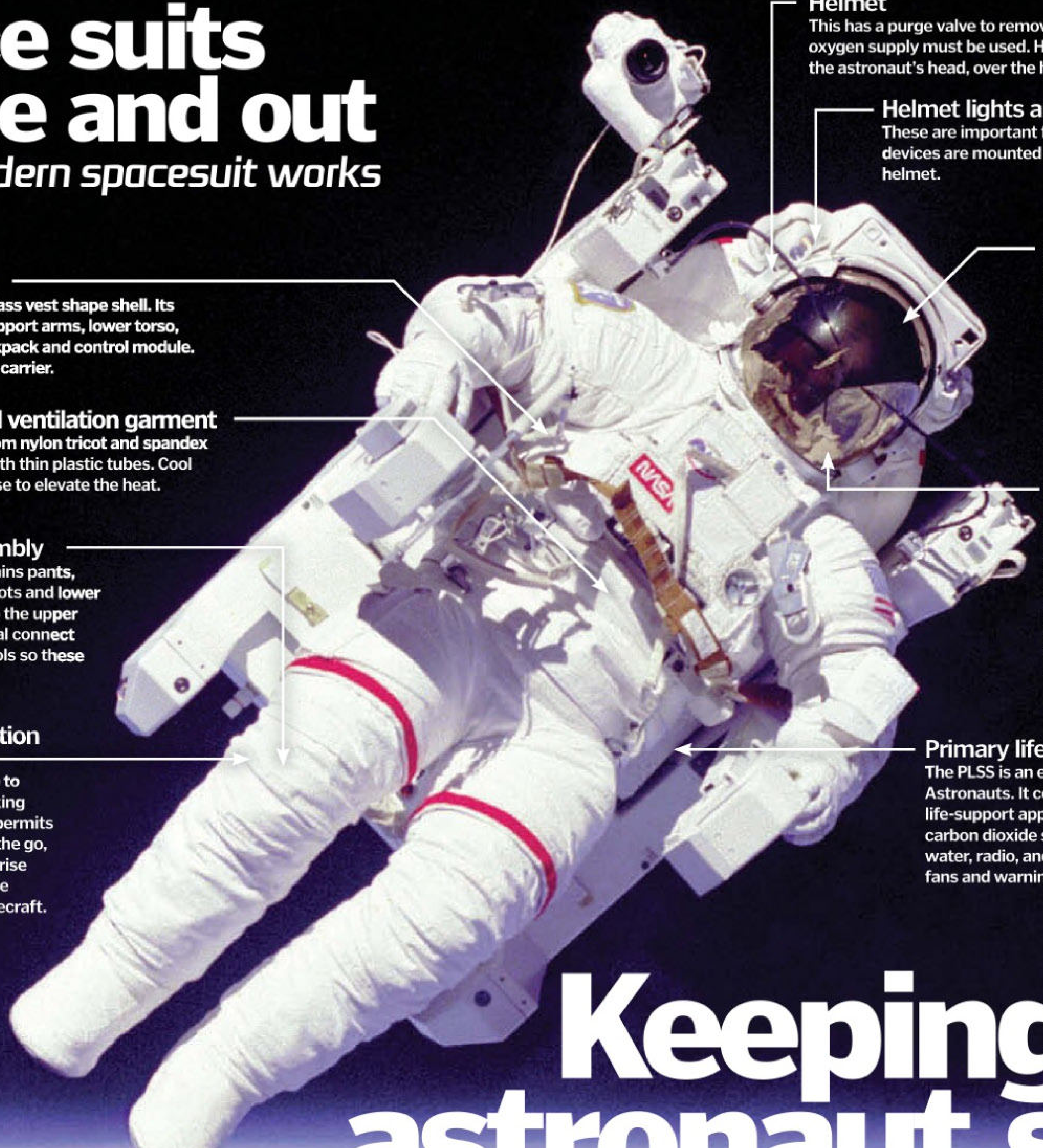
Adaptive optics are used in most astronomical telescopes such as the Palomar Observatory in California and the Keck Observatory in Hawaii.



DID YOU KNOW? A spacesuit weighs approximately 280 pounds on the ground

Space suits inside and out

How a modern spacesuit works



Helmet
This has a purge valve to remove carbon dioxide if the backup oxygen supply must be used. Here oxygen flows from behind the astronaut's head, over the head and down his or her face.

Helmet lights and camera
These are important for seeing in dark spots. The devices are mounted on the EVA and fitted over the helmet.

Communications carrier assembly
The CCA is a vital communication tool for mission control. This fabric cap contains microphones and speakers for use with the radio. This permits hands-free radio communications within the suit.

In-suit drink bag
Hydration is essential with astronauts exerting so much energy. The IDB plastic pouch is mounted inside the HUT, containing 1.9 litres of water. Astronauts drink this through a small tube positioned next to their mouth.

Primary life-support subsystem
The PLSS is an essential backpack worn by Astronauts. It contains all manner of essential life-support apparatus, such as oxygen tanks, carbon dioxide scrubbers/filters, cooling water, radio, and electrical power, ventilating fans and warning systems.

Hard upper torso
The HUT is a hard fibreglass vest shape shell. Its primary function is to support arms, lower torso, helmet, life-support backpack and control module. It also acts as a mini-tool carrier.

Liquid cooling and ventilation garment
The LCVG is produced from nylon tricot and spandex long underwear, laced with thin plastic tubes. Cool water flows through these to elevate the heat.

Lower torso assembly
This one-piece unit contains pants, knee and ankle joints, boots and lower waist. The LTA is fitted to the upper half of the EMU by a metal connect ring, looping to tether tools so these don't float away.

Maximum absorption garment
Astronauts can spend up to several hours moon-walking and the absorbent MAG permits them bathroom trips on the go, without having to pressurise and depressurise both the space suits and the spacecraft.

Keeping an astronaut safe

It may not look comfy, but every part is necessary

The modern space suit, or Extravehicular Mobility Unit – that's EMU for short – is an environmental simulator, built intricately to ensure maximum life support and mobility for an astronaut in strenuous space conditions.

The EMU is far removed from old-fashioned styles. Instead of being specifically tailored for individual astronauts, the EMU is assembled by component pieces of varying sizes that can be put together to fit any given astronaut. One size fits all. The EMU is made from a mix of hard and soft components, including nylon tricot, spandex, urethane-coated, nylon, Dacron, neoprene-coated nylon, Mylar, Gore-Tex, Kevlar and Nomex.

Dacron, neoprene-coated nylon and Gortex are integral. These are used as primary insulators in the tailored EMU. Both are vital in regulating body heat from interstellar environments. Mylar, a white fabric, produces a reflective layer, minimising UV radiation effects on the astronaut. The EMU also includes either heat exchangers to blow cool air or water-cooled garments to stop condensation within the helmet and on the visor.

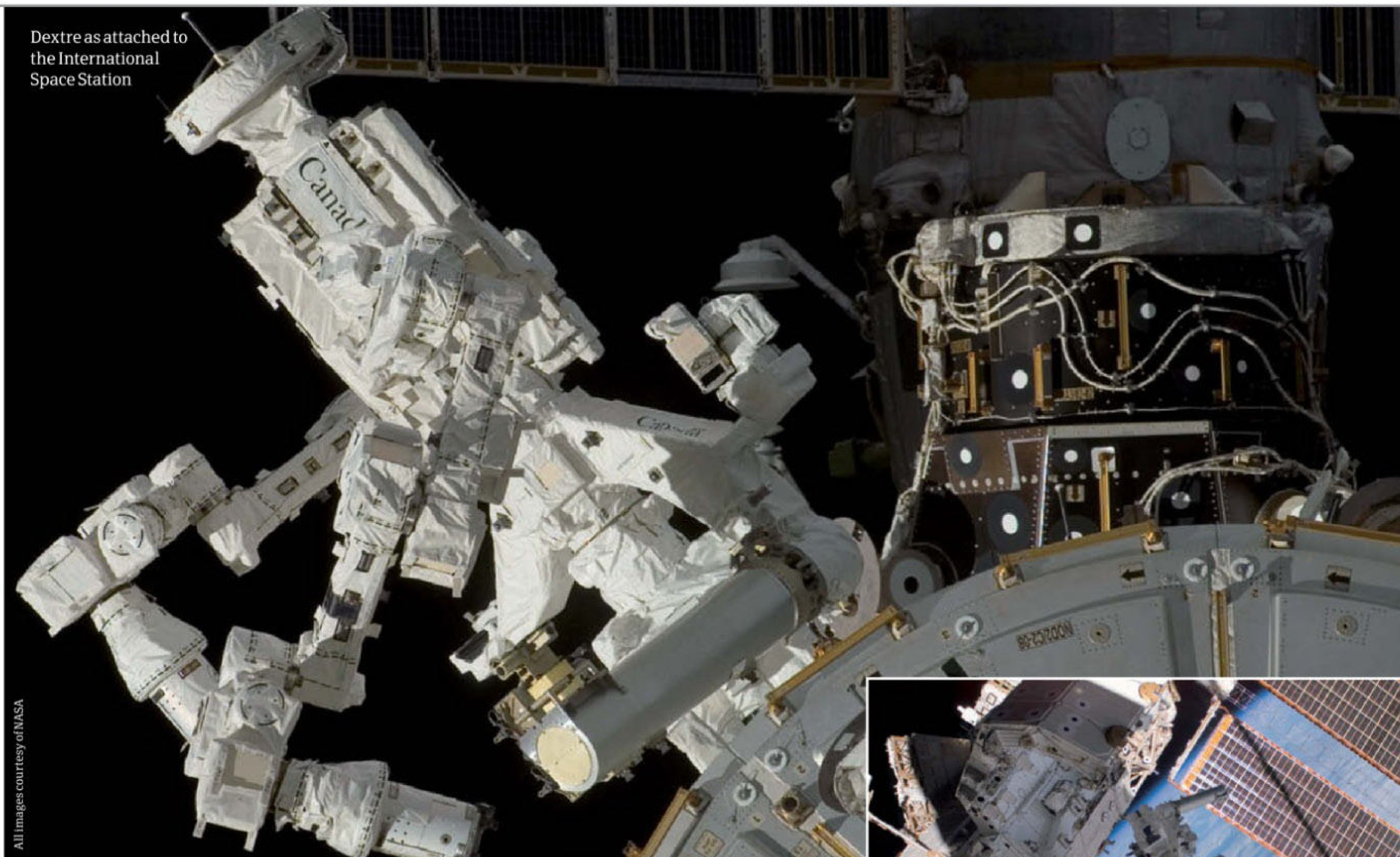
The EMU helmet is as elaborate as the main torso. These are made from clear plastic or durable polycarbonate. Coverings are included to reflect sunlight, with visors tinted to reduce sun glare, much like a pair of sunglasses.

Dacron and Kevlar are used to protect astronauts from micrometeoroids. The EMU has multiple layers of these durable fibres to ensure no tearing occurs from exposed surfaces of the spacecraft.

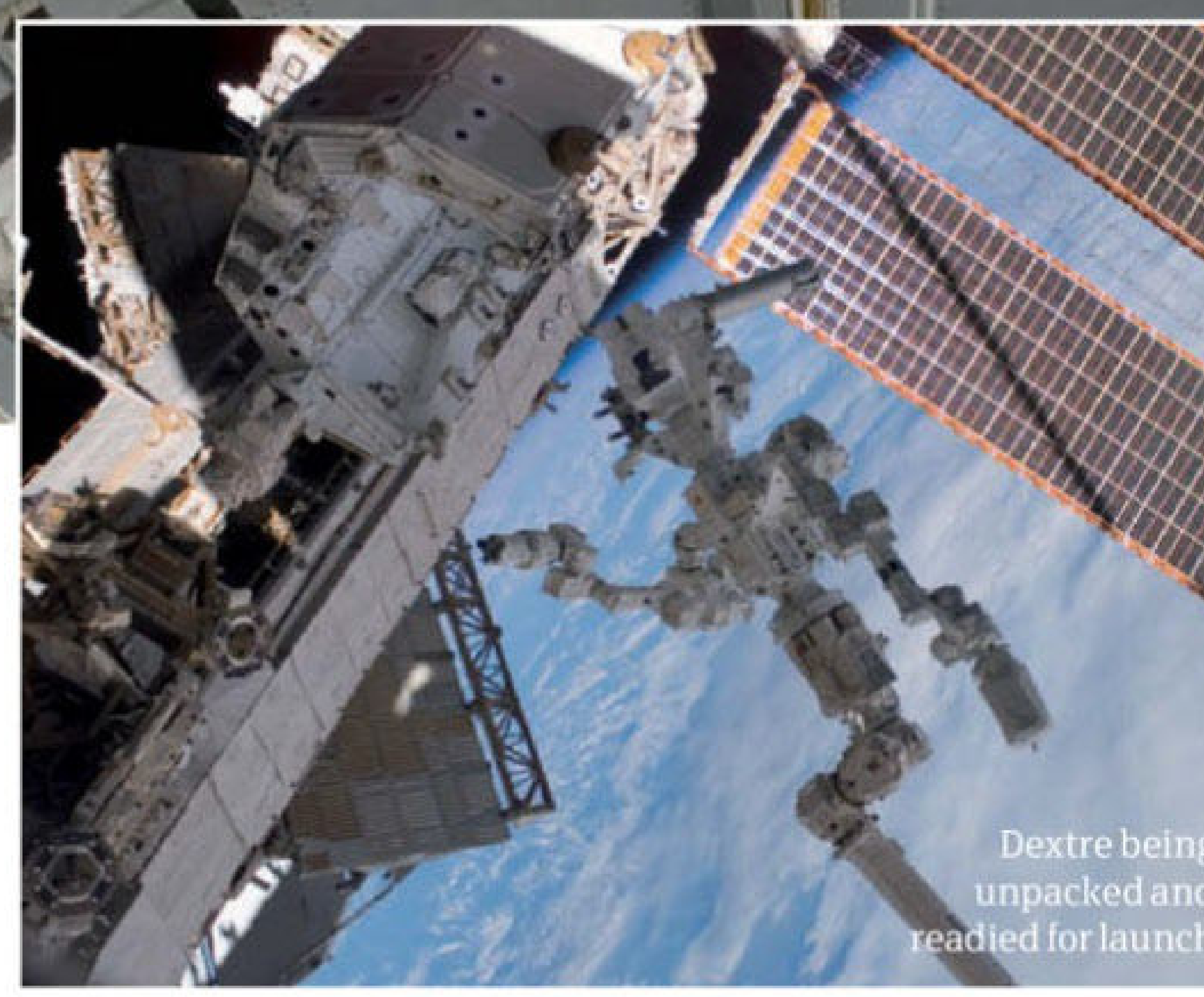
Astronaut Edwin E "Buzz" Aldrin walks on the surface of the moon during the Apollo 11 extravehicular activity

All images courtesy of NASA

"Dextre weighs 1,560kg and cannot be assembled on Earth"


Dextre as attached to the International Space Station

All images courtesy of NASA


Dextre being unpacked and readied for launch

Dextre the space robot

The robot that will fix the International Space Station

And you thought fixing your toaster was a challenge! On the International Space Station, components sometimes need repair or must be moved for scientific tests. In October of this year, the Special Purpose Dexterous Manipulator, or Dextre, will become operational after an entire year of tests in space.

Why send a repair robot into space? The primary reason has to do with saving time for human astronauts, who can focus on science experiments on the space station and because the robot is impervious to radiation and other space hazards. "Dextre also helps reduce the risk from micrometeorites or suit failures that astronauts are exposed to during an EVA (Extravehicular Activity)," says Daniel Rey, the manager of Systems Definition for the Canadian Space Agency in charge of the project.

Dextre is an electrical robot – as opposed to the common hydraulic and pneumatic robots found on Earth – because the robot itself won't require as much maintenance, space station repairs require precise movement, and there is no leakage. The robot has two large, electrically controlled arms, each with seven degrees of movement.

Each joint is controlled by a separate computer processor and runs a set of predetermined computer code. "CPUs control co-ordinated movements," says Rey, explaining that the robot is mostly controlled from the ground but does have some autonomous behaviour. "All the joints are rotary joints so they have to move in a co-ordinated fashion." The 3.67-metre tall robot weighs 1,560 kilograms and had to be 'orbitally assembled'. The colossal bot has four main tools it will use for repairs. Rey described the two important characteristics of Dextre which makes it the ultimate space repairbot.

First, Dextre uses an inverse kinematic engine to control joint movement. The 'inverse' is that the joints are instructed on the final place to move one of its repair tools, and then must work backwards and move joints to arrive at that position. Rey described this as similar to instructing a human to put a hand on a doorknob, and then knowing that you need to move an elbow, forearm, and shoulder to that position. A second characteristic is called forced moment sensor, which measures the forces applied on the joints and is used for correcting inputs from an astronaut to avoid errors and joint bindings.

The Statistics

Dextre

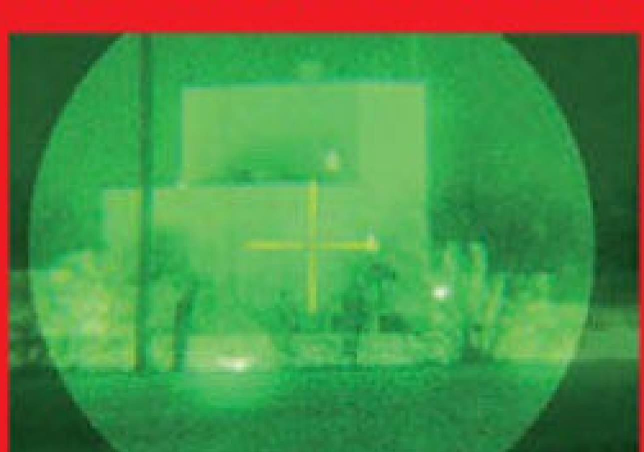
Height: 3.67 metres
Weight: 1,560 kilograms
Arm length (each): 3.35 metres
Handling capability: 600 kilograms
Crew: 98
Average operating power: 1,400 watts

This month in Technology

Our technology writers have years of experience in covering the most exciting topics from gadgets to engineering to medical technology.

67 Heatseeking missiles

72 DVD burning explained



72 How to see in the dark

TECHNOLOGY

Outside the iPhone 3GS

The main features of the iPhone 3GS explained

iTunes
Portable iTunes with wide range of audio, video and iTunes store content

Safari
Mobile Safari browser with support for HTML5 and streaming multimedia

iPod
Almighty iPod, with support for Genius Mixes, podcasts and more

App Store
A virtually endless number of ways to extend the functions of the iPhone

Calendar
Powerful calendar with support for Microsoft ActiveSync and CalDAV

Get inside the iPhone 3GS, the super-computer that lives in your pocket

The iPhone 3GS is not just a phone, it is an iPhone. The iPhone has created a whole new category for itself. With just three models – the iPhone, iPhone 3G and iPhone 3GS – it is already well on its way to conquering the world. And it's not just a phone, it's also an MP3 player, internet tablet, gaming platform, GPS device and so much more. Every hardware and software revision has bought an immense set of features that makes the iPhone even more powerful than before.

Apple has released two hardware revisions since first launching the iPhone, the 3G and the 3GS. While the iPhone 3G was more about features, the iPhone 3GS is all about speed. In other words, the iPhone 3GS is like upgrading your desktop computer with a faster processor and more RAM.

The iPhone experience is a combination of both powerful hardware and sophisticated software. Let's talk about the hardware first. Amazingly, the iPhone 3GS hardware specification is somewhat similar to a desktop computer from 1998, demonstrating just how much has been achieved in the technology sector in a relatively short space of time.

iPhone 3GS hardware design makes it one of the fastest handhelds available today. It also includes some unique features such as a digital compass which makes GPS navigation more intuitive and accurate. Support for OpenGL ES 2.0 also makes the iPhone 3GS the next generation portable gaming device.

Visionary Anthony J D'Angelo, once said "Do not reinvent the wheel, just realign it". Apple gets it. The iPhone operating system is nothing but Mac OS X realigned for portables. This brings the iPhone very close to an elegant Mac experience. The iPhone OS has a lot of Mac OS X components with few touch-specific components designed specially for the iPhone. The iPhone OS kernel, the central component of most computer operating systems, and OS X kernel use the same code base, and so do many other components.

5 TOP FACTS iPHONE

iPhone 3GS CPU power
1 iPhone 3GS CPU speed is underclocked to 600MHz from its original 833MHz. This should give it a longer life span and increased battery life.

iPhone 3GS Java mystery
2 As of now the 3GS doesn't support Java apps, despite CPU hardware acceleration for Java called Jazelle RCT Java-acceleration technology.

3D internet on iPhone
3 Mobile Safari will soon get support for OpenGL ES acceleration via WebGL, a standard to display 3D graphics on web browsers.

iPhone 3GS vs PSP
4 In terms of hardware the PSP is far inferior than the iPhone 3GS, with CPU clocked at 333MHz (vs 600MHz) and 32MB RAM (vs 256MB RAM).

Open source
5 A large portion of iPhone software is made from open source projects. This includes FreeBSD Inc, GNU FSF, SQLite, OpenLDAP and others.

DID YOU KNOW? *The iPhone was recently announced as the most successful brand ever*

Anatomy of an iPhone

Don't try this at home as it will invalidate your warranty! Instead, take a look at this iPhone we exploded under controlled conditions at the How It Works lab

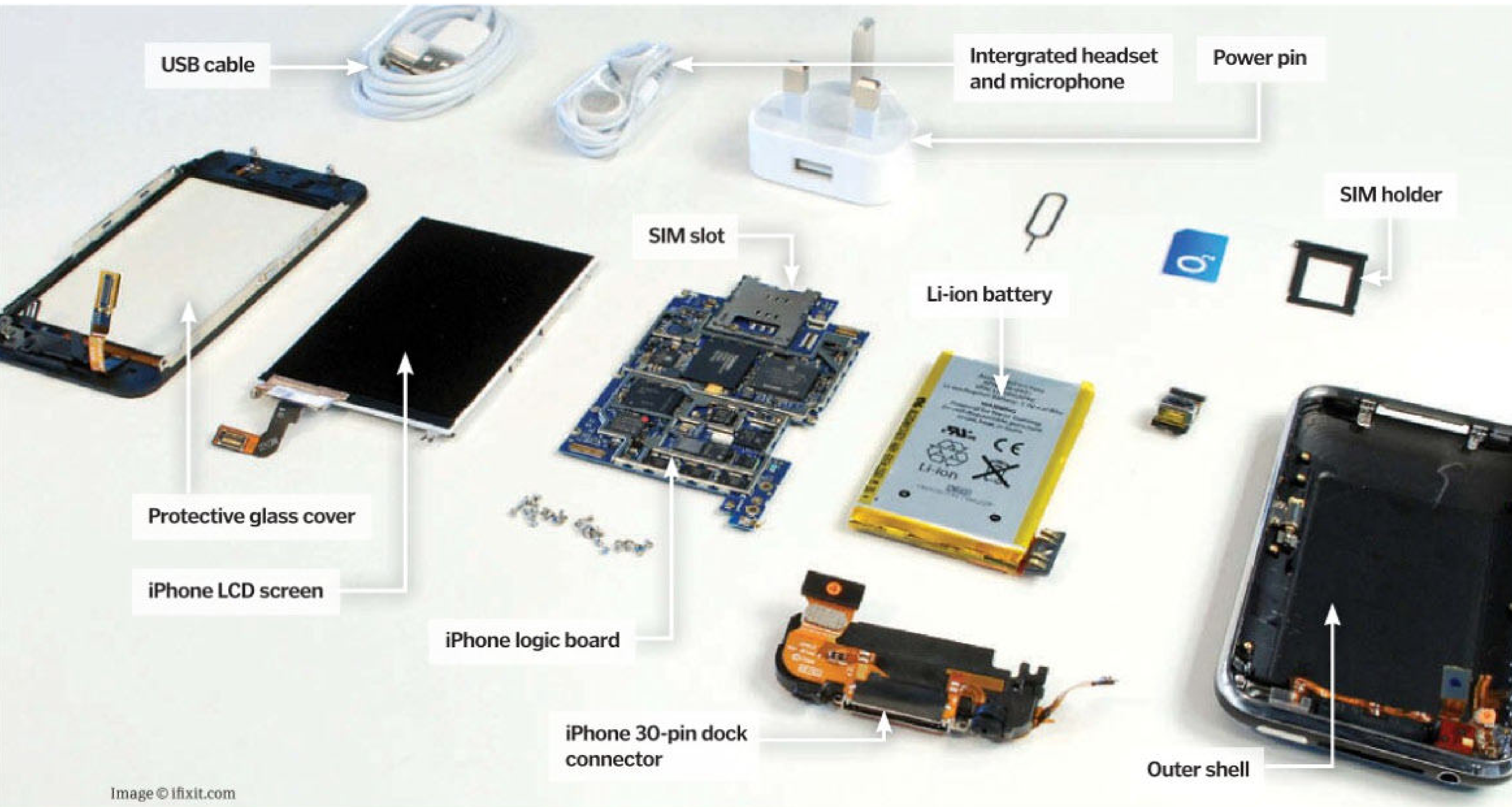


Image © ifixit.com

COMPONENT	IPHONE 3G	IPHONE 3GS
CPU	ARM 1176J(F) 620MHz, underclocked to 412MHz	ARM Cortex-A8 833MHz, underclocked to 600MHz
RAM	128MB DRAM	256MB DRAM
Storage	8 / 16 GB	16 / 32 GB
Display	320x480	320x480
Input	Multi-touch touch screen display, three axis accelerometer	Multi-touch touch screen display, three axis accelerometer, digital compass
Wireless technologies	Wi-Fi, Bluetooth 2.0	Wi-Fi, Bluetooth 2.1
Camera	2.0 megapixels with geotagging	3.0 megapixel with geotagging and automatic focus, white balance and exposure
Battery life	Up to five hours talk time / data on 3G, ten hours on 2G	Up to five hours talk time / data on 3G, 12 hours on 2G
	Up to six hours data on Wi-Fi	Up to nine hours data on Wi-Fi
	Up to 24 hours audio	Up to 30 hours audio
	Up to seven hours video	Up to ten hours video

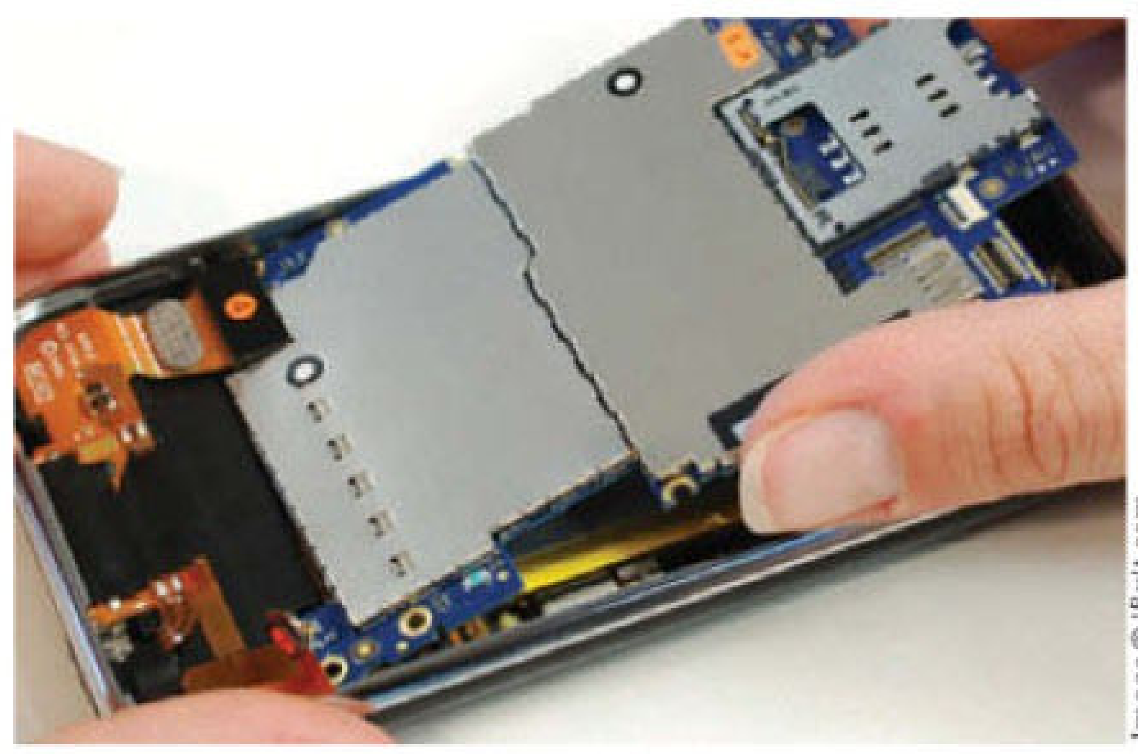
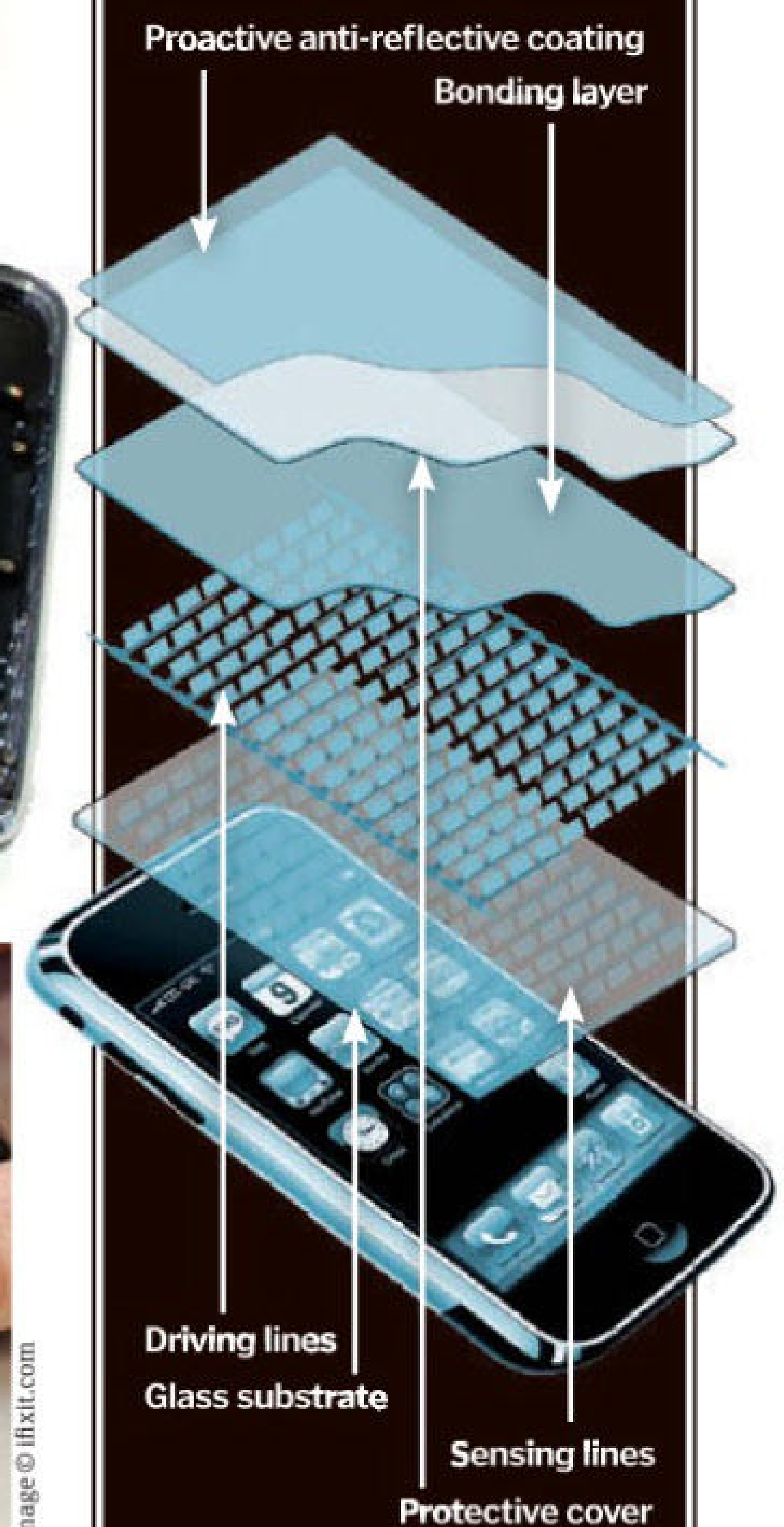


Image © ifixit.com

All in a day's work
Each component works together seamlessly to provide you with endless entertainment and functionality

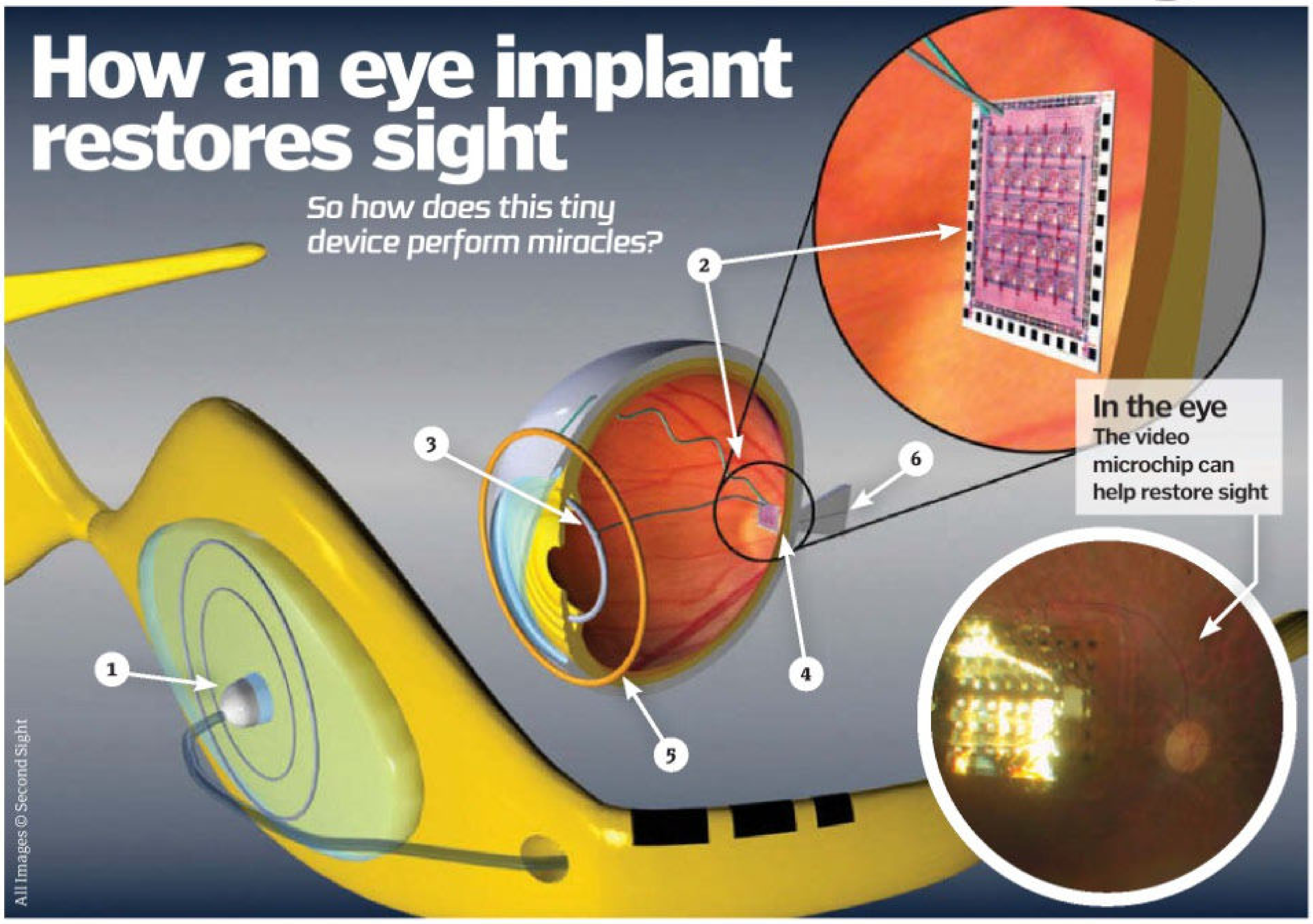
How an iPhone's screen works?

Discover the workings of the iPhone's revolutionary touch screen



Inside the iPhone 3GS

How a bionic eye works



A possible cure for blindness? You saw it here first!

This isn't quite on a par with Geordi La Forge's bionic visor in *Star Trek*, but it's no science fiction tale either.

US and German scientists have developed technology that allows the blind to see rudimentary images using a tiny camera and video processor mounted onto a pair of shades. The business end of the technology, known as the Argus II, is an electrode array that's wired to the processor and sits on the retina at the back of the eye, which in a malfunctioning eye fails to respond to the light that enters through the pupil.

The few patients that have received this pioneering implant have immediately been able to distinguish between shades and even faces, with rough images of the world consisting of blocks of light and dark. With further development we could see a day when intraocular implants can operate wirelessly, allowing full vision restoration or even enhanced eyesight.

1. Digital camera
This captures images as light and dark pixels and sends them to the video processing unit. In the not-so-distant future, greater detail and colour will be captured.

2. Retinal implant
The implant's electrode array is stimulated in a similar way to photoreceptors. Electrical signals generated by this response then travel down the optic nerve.

3. Receiver
This is implanted under the skin and having received the signal from the transmitter, it reverses the process and sends electrical pulses down a wire to the retinal implant.

4. Video microchip
The microchip receives the pixel information and translates them into electrical pulses, which it then passes on to the radio transmitter in the glasses.

5. Transmitter
The transmitter receives the electrical impulses from the video microchip, converts them into a radio signal before sending it to the radio receiver.

6. Brain
Having received the visual information from the optic nerve, the brain interprets it as a pattern of shaded spots. In time patients learn to perceive these as images.

Eco bulbs, money saver?

Why these technologies use different amounts of resources

Light is a complicated thing. It can behave like a wave or a particle. Most theories in physics talk about it behaving like a wave, when it travels fast splits into the colours of the rainbow and combines again to make white, and creates beams (think of the sunbeams you see through a window). Light bulbs however, whether energy-saving or traditional, rely on light's particle-behaviour alter-ego.

In 1905 Albert Einstein was studying how light can possibly generate energy. This is called the Photoelectric Effect. He theorised that light can create particle-like entities called photons, which throw off energy. It's possible to create light-emitting photons under the right conditions, and light bulbs take advantage of this.

The traditional light bulb had been invented a good 28 years before Einstein's theory, and utilised a variant on it. An atom of a reactive element – tungsten is usually the flavour of choice thanks to its capability to withstand intense heat – will produce light when the electrons within it are excited by an external force. This makes them temporarily speed up and widen their orbit around the nucleus in the middle of an atom. When they're pulled back to their original orbit, they throw off a photon. Traditional light bulbs use heat passing across a filament of tungsten to do this. Energy-saving light bulbs use a tube filled with argon gas and mercury vapour. When electrons move from one end to the other, they cause the mercury atoms in the tube to throw off light in the ultraviolet range.

Producing heat requires much more energy than creating enough charge to excite the mercury atoms inside a fluorescent tube. This means that energy-saving light bulbs are exactly that: they require less energy to be pumped into them in order to function. And as they don't heat up the element that creates the light, it also lasts longer, giving them their extended life span.

DID YOU KNOW? In a fluorescent tube the visible light is produced as a secondary effect of the mercury vapour throwing off photons. The ultraviolet photons react with the phosphor coating on the inside of the tube and this produces visible light.

THE STATS AIM-9

TOP SPEED **Mach 2.5** LENGTH **3.0m** WARHEAD **9.5kg**
WEIGHT **85kg** RANGE **11 miles** COST **$85,000**

DID YOU KNOW? *The missile flies towards its target at speeds of 1,900mph*

Missiles in action: AIM-9 Sidewinder

This air-to-air missile mercilessly seeks out its prey – there's little chance of escape!

All images © Raytheon

Named after a venomous snake that is sensitive to infrared and so can sense the heat of its prey, the deadly Sidewinder missile does much the same.

First tested in 1953, the Sidewinder is a heat-seeking, short-range air-to-air missile used by fighter aircraft. Once launched, it will fly towards a hot target – usually the engines of an aircraft or another missile.

The key to the system is hidden in the nose of the missile. The seeker consists of an array of sensors that react to infrared light; similar in principle to the CCD sensor in a digital camera but simpler in that it only judges its surroundings as 'very hot' or 'not very hot'. In other words it can 'see' heat. The sensors, plus its assembly of mirrors and lenses, spin off-centre so that they can scan a wide vista and also work out where the heat is in relation to the missile. For instance, if the target is over to the right, the sensors will detect more infrared when they are aimed in that direction.

The sensors feed information to the guidance control system that, in turn, move the fins at the back of the missile to steer the Sidewinder towards the target. Or rather, aim it at a point slightly ahead of the target to ensure that it doesn't end up chasing it and never catching it. This is called proportional navigation and effectively anticipates where the target will be at the point of impact.

In fact, the Sidewinder doesn't actually impact with its target, but is designed to explode just before it hits it, to ensure maximum damage. Lasers positioned behind the forward fins emit light and, when the missile is close to the target, the light bounces off it and back to sensors on the missile, telling the systems to trigger the warhead.

The Sidewinder is launched from an aircraft and is initially propelled by a rocket motor that hurls it forward at a speed of Mach 2.5 (about 1,900mph). Once the fuel has been used up, the missile glides the rest of the way to its target.

The warhead

The front mid-section of the Sidewinder is packed with explosives. Like the rest of the missile, though, this 9kg warhead is highly sophisticated. It consists of a high explosive wrapped with around 200 titanium rods, plus an initiator explosive.

When the missile is within range of its target, the low-power initiator is activated. This, in turn, ignites explosive pellets which then cause the main charge to explode. This blasts the titanium rods apart into thousands of fragments which hit the target at high speed, causing cataclysmic damage.

A safety device in the missile means that the warhead cannot be activated unless the missile has been accelerating at 20g for five seconds, therefore ensuring it is at least 1.5 miles away from the launching aircraft.

ON THE MAP

Deployment

It is estimated that Sidewinder missiles have killed around 270 people worldwide over the last 50-plus years. Over 110,000 missiles have been produced for 28 countries and just one per cent of them have been used in combat. Here are just some of the war zones where the missile has seen action:

1. Second Taiwan Strait crisis
Date: 1958
Location: Taiwan Strait, Taiwan

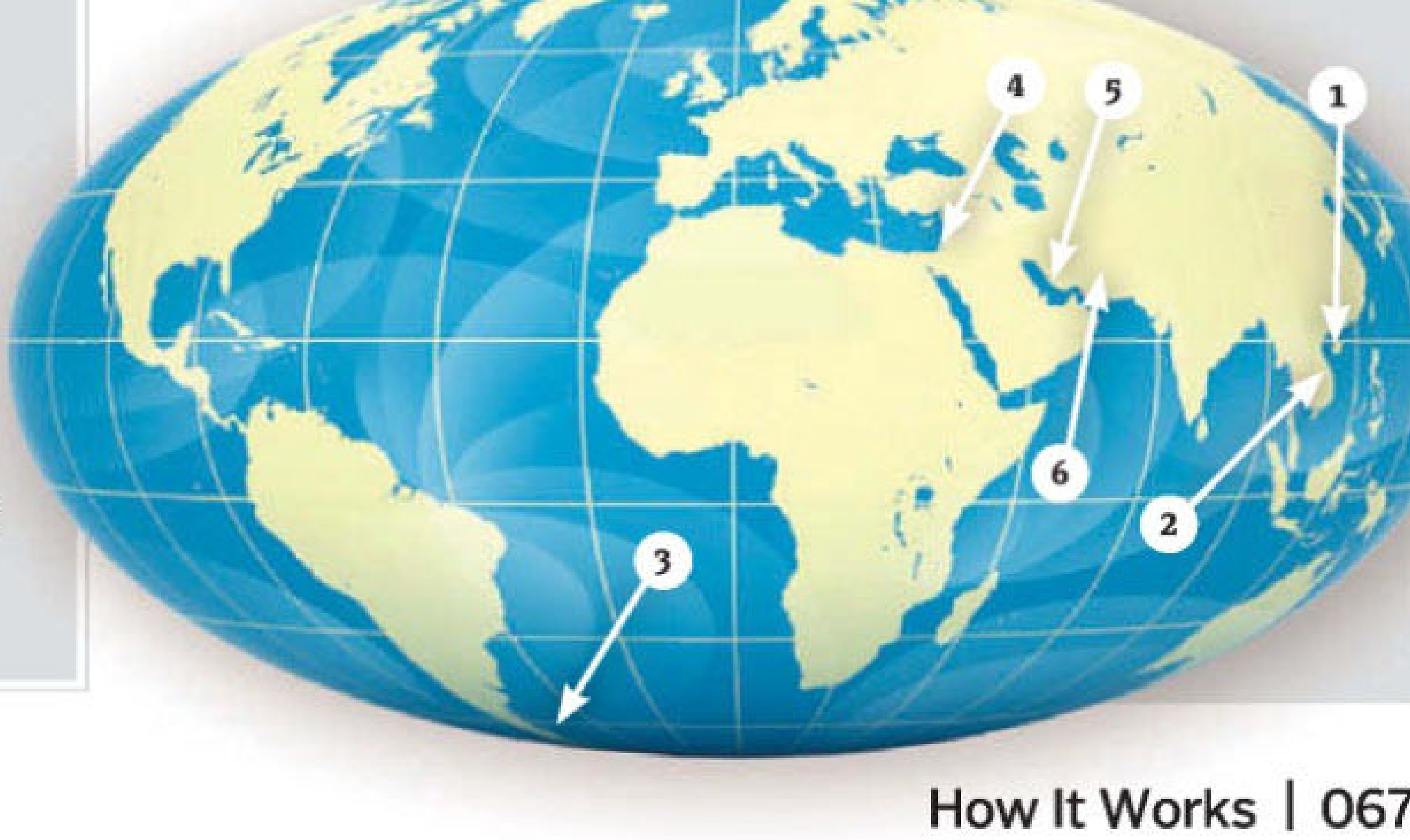
2. Vietnam war
Date: 1959-1975
Location: North Vietnam

3. Falklands conflict
Date: 1982
Location: Falkland Islands

4. Lebanese civil war
Date: 1975-1990
Location: Bekaa Valley, Lebanon

5. Gulf war
Date: 1990-1991
Location: Persian Gulf

6. Soviet-Afghan war
Date: 1979-1989
Location: Afghanistan

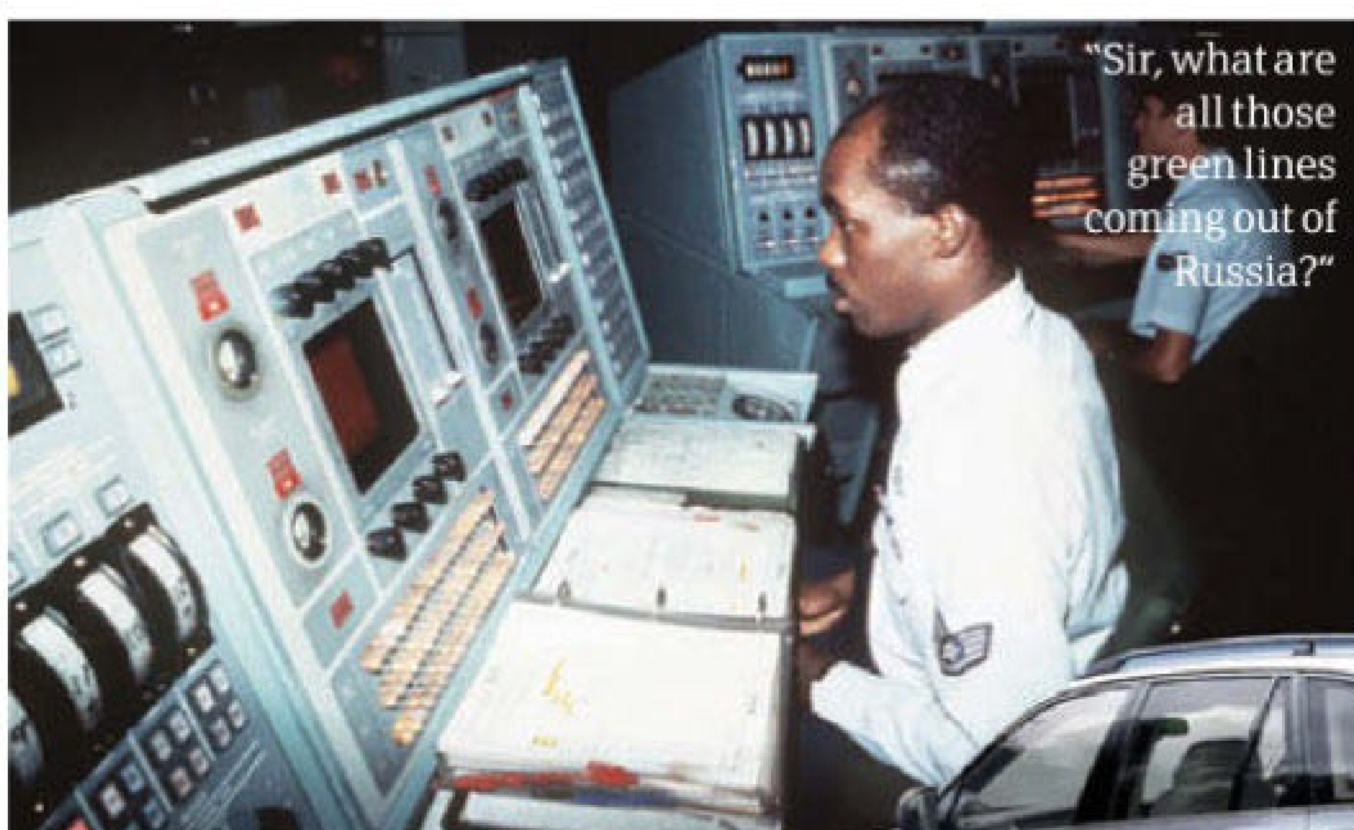


How radar finds objects

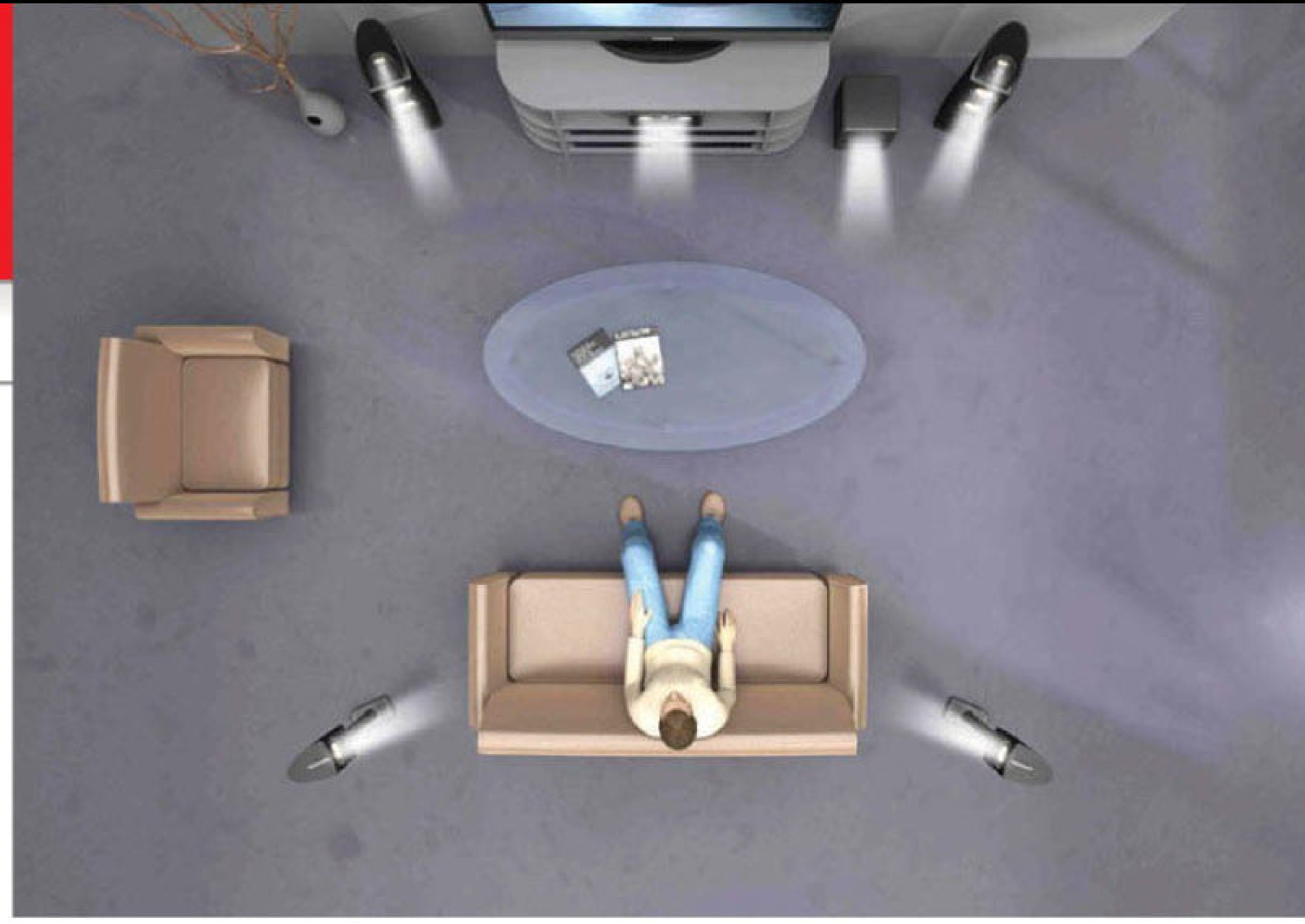
How sound inspired radiowave observation

Radar uses a radiowave-based version of echo location to find moving and stationery objects. When you make a noise in a space that echoes, the sound is bounced back to you – you hear it again a moment or so later. If the sound is moving, somebody standing still and listening to you will hear the sound go up and down as it moves past them. This is called the Doppler effect.

We can't go around shouting at aeroplanes in order to find them, no matter how frustrating Terminal 5 can be, so instead radiowaves are used. They produce exactly the same phenomenon as sound. For example, an aircraft is fitted with a radar transmitter. When another transmitter sends a burst of radiowaves in its direction, they're bounced back. The speed with which they bounce back, and the wavelength of the waves, determine where the aircraft is and the rate at which it's moving relative to the transmitter.



"Sir, what are all those green lines coming out of Russia?"



Understanding digital sound

We've come a long way from the gramophone, but what exactly is digital sound?

Record collections may still be en vogue, but both vinyl and cassette mediums represent an archaic analogue technology that has been superseded since compact discs came to the fore. Imagine the pits and grooves in a record or the magnetically charged surface of tape that store the information as a variable wave: in contrast, digital sound is stored as a series of distinct peaks and troughs, rather like the battlements of a castle. Translating from analogue to digital is called encoding and in terms data storage, it saves an enormous amount of space.

This is the basis of Dolby's digital audio technologies and the encoding process allows companies like Dolby to tease apart digital sound into separate channels for a surround sound experience: 5.1 surround, for example, consists of a left and right channel communicating movement, a focused centre channel for dialogue, a pair of surround channels and a resonant low-frequency bass.

Starting your car without a key

Keyless car ignition is becoming more common – but how does it work?

Necessity is the mother of invention and these days, gadgets are necessary. Keyless ignition simply allows the motorist to come within range of their vehicle then press a button to start the engine. It uses a technology called RFID, or radio frequency identification: an RFID chip (the lock) is placed inside the car that will unlock the ignition system when activated. Only its corresponding fob (the key) can activate the chip using a radio signal, which works like a barcode in a supermarket. RFID used to use a 40-bit encryption system that wasn't particularly strong and proved fallible, with high-profile victims of failed RFID security that include David Beckham, who lost two BMW X5s with keyless ignition to thieves.

On the plus side, there's no physical key to replicate, keyless systems include security measures that prevent you from locking your key inside and it has more practical significance for disabled drivers.

DID YOU KNOW? It's not carbon dioxide that actually makes the bubbles in a drink – it's dirty glasses. CO_2 is invisible; what you see is its silhouette outlined by trace elements.

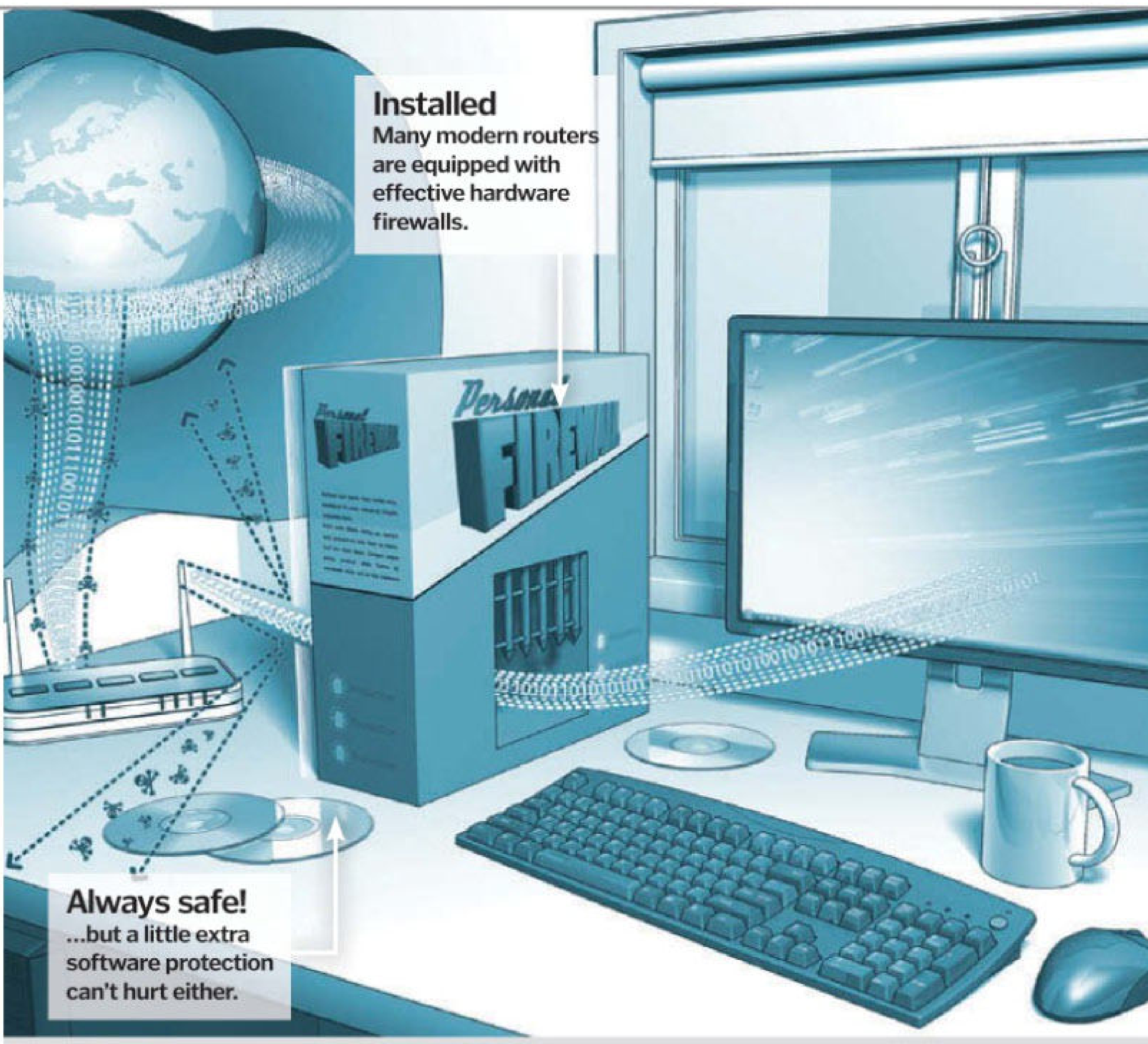
Creating the perfect frothy beer head

Two pints of CO_2 and a shot of liquid nitrogen

A widget is a small plastic ball with a hole in one end, which is added to a beer can.

Beer is loaded with gaseous nitrogen and carbon dioxide, and a chaser of liquid nitrogen just before canning. When these elements are under pressure they're relatively inert, but remove the pressure (by pulling the ringpull) and they expand. If they evaporate in a thick liquid they don't get through as much of the liquid as they would in a thin one before they've been dissipated, because the speed of evaporation is constant, but the distance they travel depends on how fast they can move. This movement creates the head on your beer. The nitrogen-filled widget pulls beer into it and shoves it back out again at high speed when the pressure of the can is released, exciting both elements to move through the liquid faster and aerating it with the evaporating gases.

DID YOU KNOW? *Hans Geiger was involved in Nazi Germany's attempt to build an atomic bomb*



Protect your PC with firewalls

Your PC is under attack – defend it!


ZoneAlarm is one of the most popular free Firewalls

Hackers, viruses, spyware and trojans are ganging up on us, threatening the safety of our computers and, heaven forbid, our privacy. Attacks come from people using the internet. They send rogue data to your PC via the phone lines or enable spyware to send private details out. Without a firewall, you leave your computer open to attack but put one in place and your PC becomes much more secure, giving you peace of mind. It is important to fight back and that is where a firewall is essential.

In simple terms, a firewall monitors and filters the information that travels through your internet connection into your PC. Think of a firewall as a physical brick construction in a building that prevents fire spreading from one area to another. Firewalls have filters that allow certain data to pass and others to be halted at the gate. The filters can block certain IP addresses or domain names, control particular protocols, give access to certain ports and bar others, or discard any information with undesirable words and phrases. Firewalls can be set up in one of two ways – they can allow all traffic to flow until certain criteria is met or they can prevent all traffic until certain criteria is met. Either way, a good firewall analyses and checks both inbound and outbound traffic against the filter's set of rules, discarding any rogue data. This not only prevents damage to your PC but also helps to stop spyware sending out any data you wish to keep private.

It is possible to buy a hardware firewall too. It operates as a standalone device, such as a router, that is configured via a web-based interface. Hardware firewalls tend to be used to protect networks of computers and are not essential for home computing.

Getting to grips with Geiger Counters

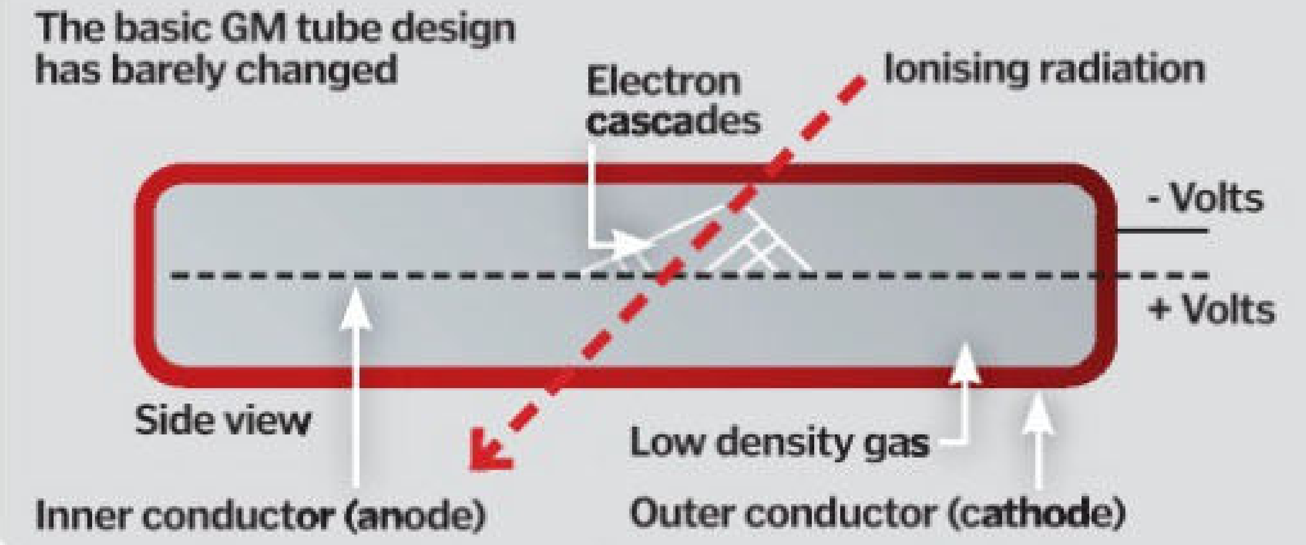
First developed at the turn of the 20th Century, Geiger Counters still work in much the same way

The Geiger Counter was invented by Hans Geiger and Ernest Rutherford in 1908 to detect alpha particles, one of four main types of radioactivity (the others being beta, gamma and x-rays). It was later modified by Geiger and his student Walther Müller to detect the others and again in 1947 by Sidney Liebson into the Halogen Counter – which is the technology still widely used today.

A Geiger Counter typically consists of four parts; a power supply, a visual and audio readout and the crucial Geiger-Müller tube that measures the radiation. The GM tube is filled with a low pressure inert gas such as neon, helium, argon and, most commonly today, halogen. It is usually coated with metal or graphite to create the cathode, while the anode wire, charged with around 1,000 volts, passes through the centre. GM counters work by pointing at a suspected source of radiation, which releases pairs of ions and electrons in the gas that are attracted to the negative cathode or positive iode. It is this cascade of charged particles that creates the electrical current measured by the audio readout, usually an oscilloscope or LCD display, in milliroentgens (or microsieverts) per hour. It is the readout or speaker that creates the 'click' for each particle registered; the more rapid the clicks, the more intense the radioactivity.

> *"Geiger Counters were used to prevent human exposure to harmful levels of radiation"*

Historically, Geiger Counters were used to prevent human exposure to harmful levels of ionising radiation which can cause anything from minor skin burns to fatal cancers and genetic damage. At the height of the Cold War they were routinely supplied to civil authorities and even hospitals in preparation for nuclear war, however these days their uses are far more diverse, ranging from astronomy, medicine and engineering to military environments.



The basic GM tube design has barely changed

GPS naviga

GPS devices have become the must-have car accessory and these devices now help millions of people find their destinations every day. It's all made possible by a network of satellites orbiting the Earth at over 8,000mph…

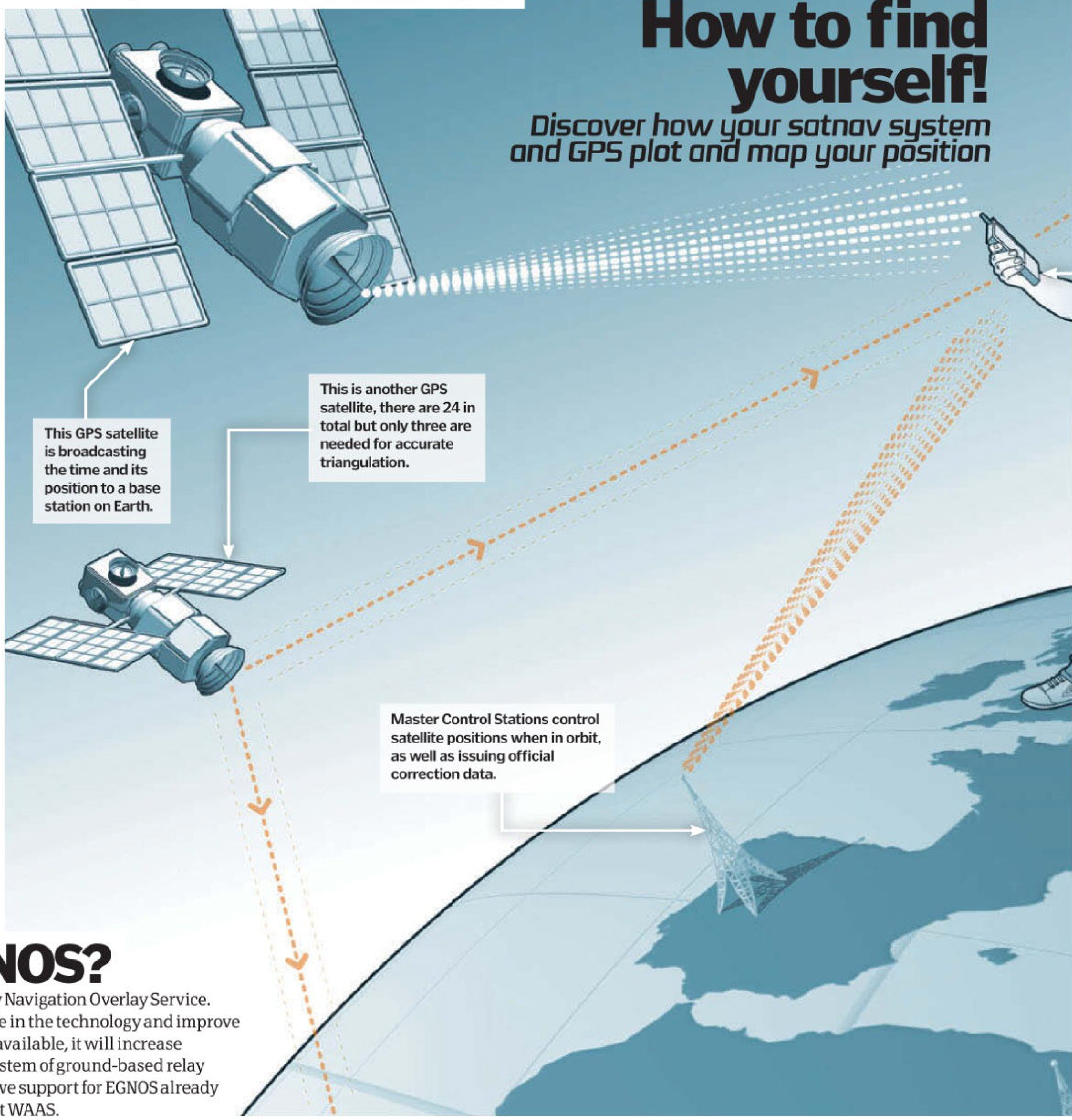
Orbiting the planet 11,000 miles above us, satellites are constantly sending signals down to Earth. These satellites and GPS technology started out as part of the USA's military attempt to improve missile accuracy. The satellites send a constant stream of signals broadcasting their exact position to Earth, where a GPS or satnav system can receive it.

The signal sent to your receiver will tell it how far away the satellite is and its direction. Once the receiver has this information from three different satellites it can start calculating your position, using triangulation. There are 12 satellites on each side of the Earth at any one time, as they have to cover the whole planet. These will be at different positions in the sky. Once you have four satellite signals, your receiver can start to calculate altitude as well as position. The more signals you receive, the more accurate the results will be during the journey.

New systems will become available over the next few years that improve on the average 15m accuracy. These systems rely on new satellites that orbit to stay in exactly the same position, and ground stations to relay the signals. In Europe the system in development is called EGNOS and promises accuracy to 2m.

How to find yourself!

Discover how your satnav system and GPS plot and map your position



What is EGNOS?

EGNOS is the European Geostationary Navigation Overlay Service. EGNOS will give Europe independence in the technology and improve accuracy. When the service becomes available, it will increase accuracy from 20m to 2m through a system of ground-based relay stations. Many handheld receivers have support for EGNOS already built in, along with the US counterpart WAAS.

Military beginnings
1 The Global Positioning Satellite System (GPSS) was originally designed for the American military to make their nuclear missiles more accurate.

Deliberate inaccuracies
2 The GPS system had in-built inaccuracies until 2000. Before 2000, the US military degraded the signal for civilian use.

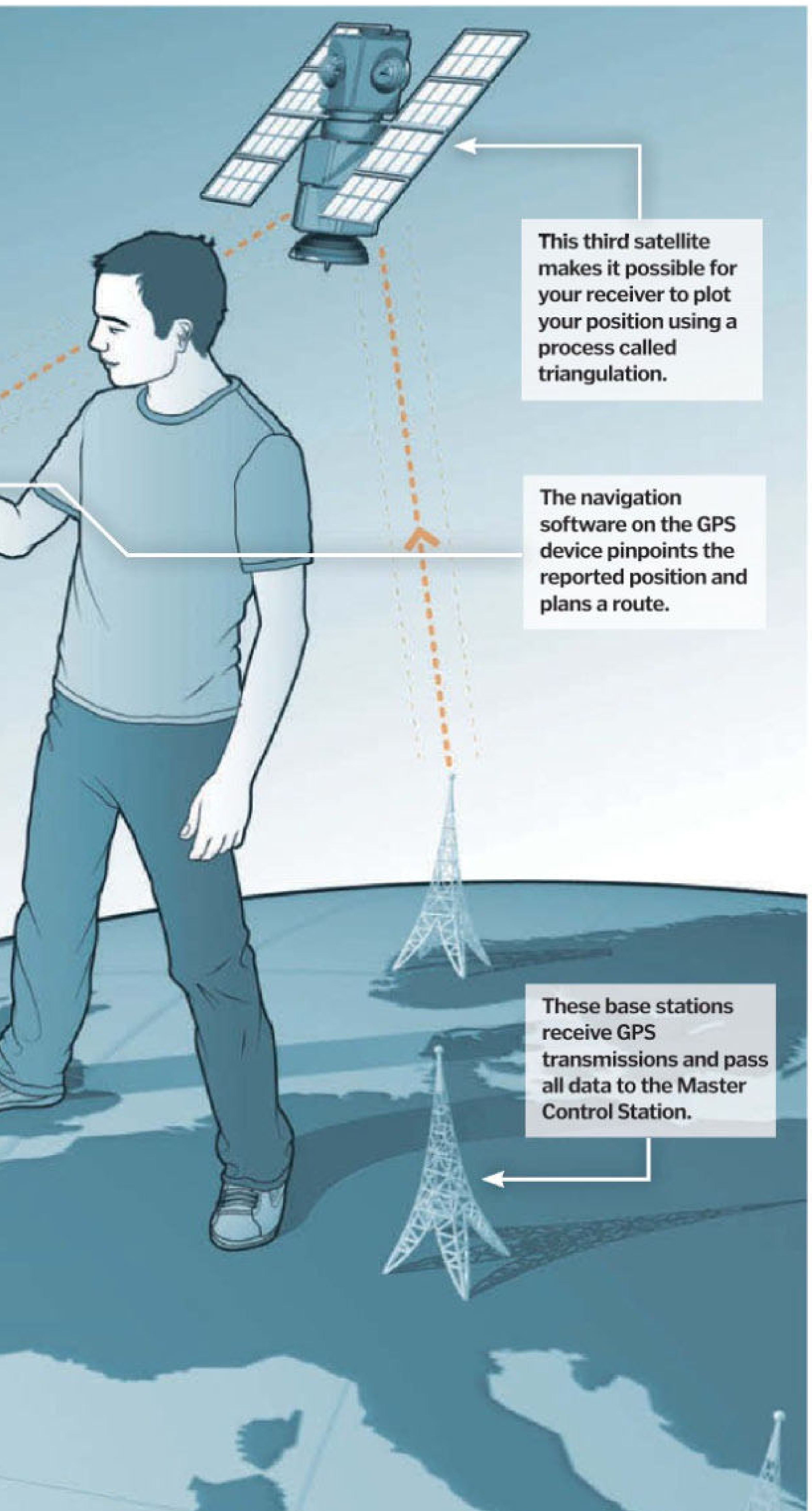
European GALILEO
3 The European satellite system GALILEO is scheduled for completion in 2010. Its satellites will broadcast GPS data to the highest accuracy.

Signal problems
4 Early GPS receivers had poor reception in built-up areas. Most receivers now have chipsets capable of receiving a strong signal everywhere.

You know, but others don't
5 A GPS receiver will tell you where you are, but won't tell others. The tech used in many GPS and satnav devices can only receive messages.

DID YOU KNOW? An in-car GPS updates every second to maintain an accurate position

tion



Get the kit

GPS kit comes in many different guises, so take a look at our pick of the best devices

Garmin Edge 705

Price: £260

Operating system
Proprietary
Software
Proprietary
Map coverage
Basemap
Installation
Pre-installed on internal flash memory
Additional storage
microSD card
Dimensions
109 x 51 x 25mm
Weight
104.9g
Display
2.2 inches (176 x 220px)
Additional features
Heart rate monitor, speed/cadence monitor, online connectivity

A GPS tool for cyclists, the Edge 705 is a fully featured GPS complete with heart rate monitor. The device is compact and lightweight and it doesn't feel too rugged, although the buttons on the sides of the unit are protected against the elements. The package comes with two bike mounts and plenty of cable ties to fix to your bike securely.

Garmin nüvi 1340T

Price: £219.99

Operating system
Proprietary
Software
City Navigator Europe NT 2010
Map coverage
Western Europe
Installation
Pre-installed on internal memory
Additional storage
microSD card
Dimensions
122 x 75 x 16mm
Weight
161.6g
Display
4.3"
Additional features
TMC receiver (life-time subscription), safety camera database

Part of Garmin's new in-car range, the nüvi 1340T features a pedestrian mode that has the ability to guide you around the London Underground. When driving you can pick from a 'Less fuel' preference option which is designed to calculate routes using the least amount of fuel. Overall it's a good-looking and functional update to the series.

Forerunner 405

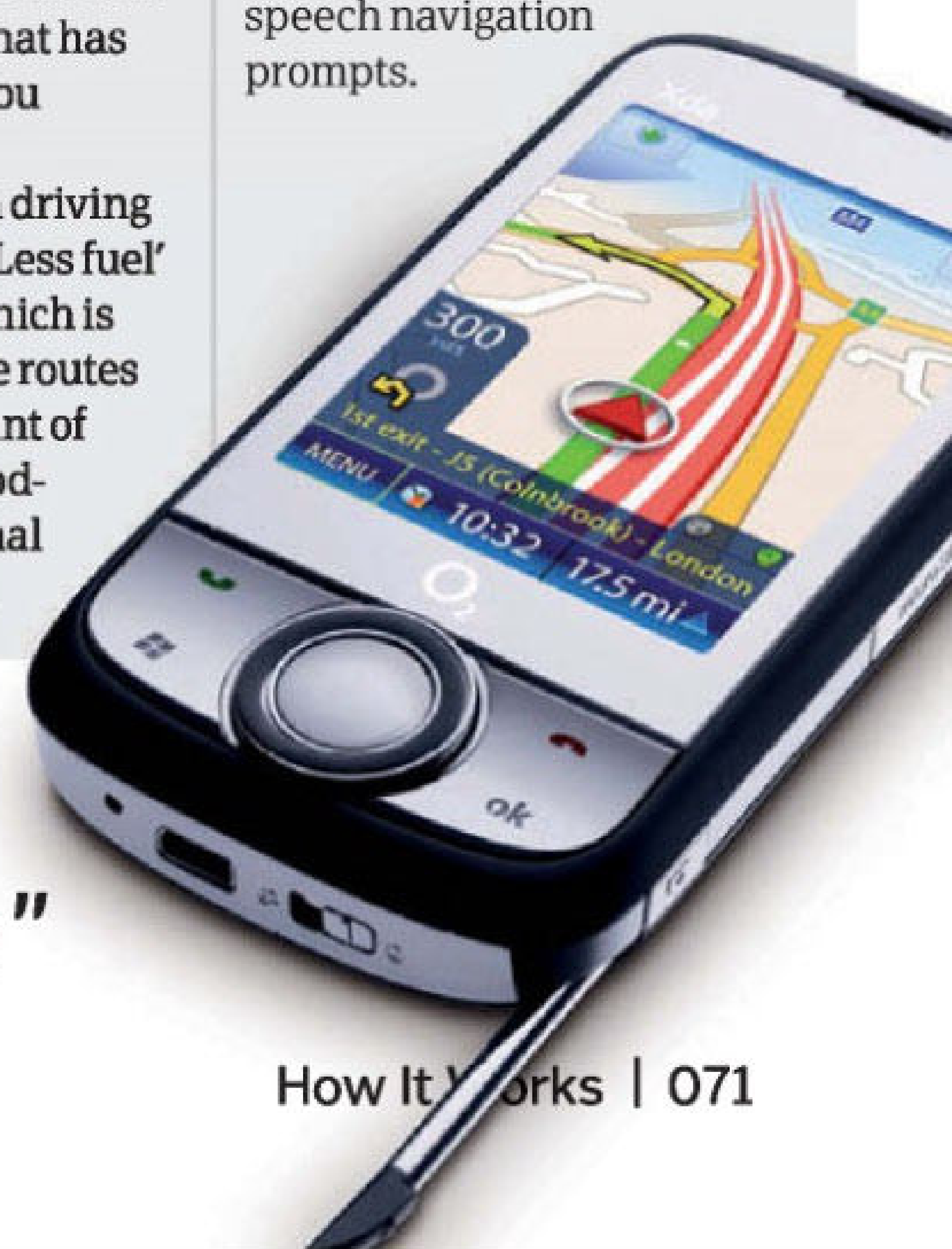
Price: £229

This feature-packed watch includes a high-sensitivity GPS receiver that tracks your route and speed, plus a heart rate monitor to keep you within your optimal range of effort. Navigating all the watch's functions is done via the innovative touch bezel on its face. Also included is a Virtual Partner who can set a challenging pace as you look to improve performance.

Garmin nüviphone

Price: £TBC

Garmin has recently entered the mobile phone market with a brand new device that combines the navigational functionality of the nüvi range of PNDs with an iPhone-style mobile phone, available in bundles with ALK's excellent CoPilot Live navigation software. High-end navigation features are included, with European map coverage and text-to-speech navigation prompts.



"Once the receiver has this information from three different satellites it can start calculating your position using triangulation"

DVD burning explained

Just what happens after you click the burn button?

So you've got a DVD burner and some software like Nero or Toast and you want to transfer some video you've shot to DVD. Ever wondered just how your PC and that software accomplishes this task? Read on…

Hitting the Burn button will start the burning life cycle, which is essentially a four-step process. The first step is the process of converting the existing video file into a format that can be read from the DVD. This is known as transcoding and will take a proportionate amount of time depending on the file size. The next part in the process is building, which is the construction of the disc. This is where menus, links and navigation are put together to make sure they work on the disc.

The next stage is the big one where the information is written to the disc. This involves the physical process of transferring the data from the hard drive and placing the data onto the disc. How long this part of the operation takes depends on a number of factors, including the DVD writer's burnspeed capabilities. Finally, there is the lead out, which marks the end of the burning process. This ensures a player or program does not get confused and tries to read any further into the disc.

Burning your own video content to a recordable DVD disc doesn't hold any legal issues, the content is yours. However, commercial DVD movies do have copyright issues. It is illegal to make even a single copy of a DVD and the majority of DVD-burning software does not allow the copying of protected material. There is commercially available software that'll remove copy protection, allowing users to make backups of their favourite movies. AnyDVD (www.slysoft.com) is a program that removes copy protection on a DVD movie as soon as it's inserted into the drive. This then allows users to back up the movie using a DVD burning tool. Theoretically, individuals could face up to two years in jail, an unlimited fine and possible civil action from the copyright holders.

The anatomy of a DVD disc

1. Recording layer
A dual-layer disc has two recording layers. Layer 0's metallic coating is altered to become translucent, allowing the laser to pass through it when focused on Layer 1.

2. Wobbled groove
This is embedded in the plastic surface and provides the recorder with the timing information needed to place data accurately on the disc.

3. Pits
Pits or bumps, depending on which side you look from, are where the laser heats up a tiny pinpoint of dye. This changes the dye's physical build, burning on data.

4. Laser
DVD recorders use a red laser to read and write DVDs. The reading laser is not as strong as the writing laser because it does not need to heat up the recording layer.

Night-vision goggles

From air-sea rescue to counter surveillance, night vision goggles have literally changed the way we see

Night vision typically utilises two types of technology; thermal imaging (infrared) and image intensification or light enhancement, of which the latter is the most portable and therefore suitable for use in night vision goggles. Light Enhancement devices take the photons present in ambient light (typically moon or starlight) from the front lens, pushing them through a photocathode tube that converts them into electrons, a microchannel plate containing millions of photoelectric channels that multiplies them before bouncing them against a phosphor screen to convert back into the distinctive green-tinged image seen through the eyepiece.

Night vision was first developed for tanks by both sides in WWII before being made portable for sniper scopes in Vietnam and finally for goggles in the Fifties. Now used by military, police and rescue operations worldwide, devices are classified as Generations 0-3, with consumer (Gen 1) devices starting from as little as £200 to far more expensive and sophisticated Gen 3 devices for military and counter-surveillance purposes.

I can see you…
No longer will total darkness prove an obstacle

DID YOU KNOW? *The first digital camera to go on sale was a Kodak DSC-100 in 1991 hosting a petite 1.3 megapixel sensor*

How does your DSLR camera work?

Many camera owners are content to shout "Cheese" and push the shutter button to get an image, but we go under the hood to find out exactly how it happens

The dawn of the digital format has revolutionised the imaging industry and in turn the way we work our cameras. Furthermore the internal DNA of the camera body has been entirely restructured to make way for the new electrical system; or has it?

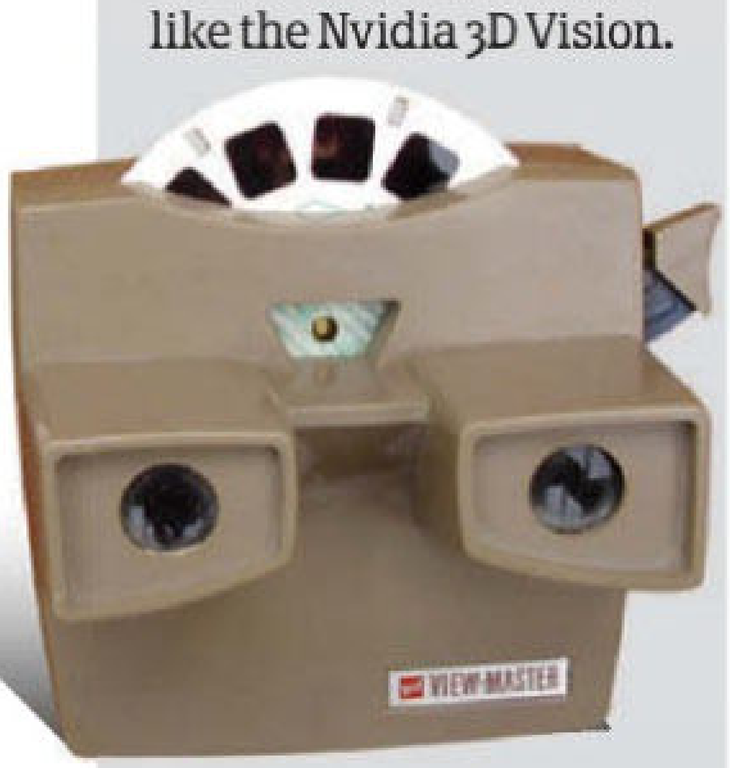
In fact film and digital cameras operate in a similar manner. Varying the size of the lens's diaphragm (aperture) in tandem with the amount of time the shutter is open, focusing light onto the image detection material, the only difference being that this is now received in an electrical rather than chemical form.

A DSLR (digital single-lens reflex) camera employs a mechanical mirror system that directs the light travelling through the attached lens upwards at a 90 degree angle allowing the photographer to compose the shot through the viewfinder. As the shutter button is pressed the exposure takes place: the mirror swings out of the way and the shutter opens allowing the lens to project the light on to the image sensor. In low light scenarios the shutter will need to stay open for a longer period of time for the image to be recorded, this is why photographers support their cameras with tripods as the smallest degree of camera shake will disturb the quality.

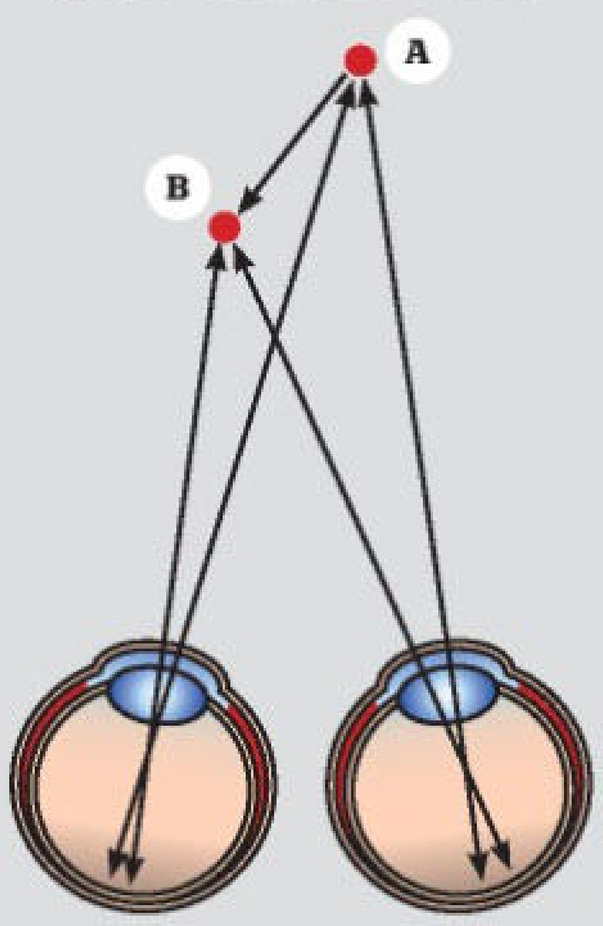
The sensor is formed of millions of pixels laid out in thousands of rows and columns: the more pixels or dots of light, the higher the megapixel count and in theory the higher the resolution. The light travels through a colour filter above the individual sensors and is converted from light waves into an analogue signal which is then processed through a digital convertor. Next the conversion is fine tuned through a series of filters that adjust aspects such as white balance and colour. The resulting image can be made into a JPEG by compressing the file size and discarding unnecessary pixels. The final image is shown on the LCD.

Early 3D viewers

Over 150 years ago, the first device to use the visual depth perception trick – called a stereopticon – projected an image for both eyes that made a photograph look more realistic, although not in 3D. It wasn't until the original View-Master, which debuted in 1939, and its ability to show a slightly different image to the left and right eye that made 3D viewing possible. Today, the technique is still used, even in the high-end IMAX theatres and using computer monitors with products like the Nvidia 3D Vision.



View-Master
The View-Master, released in 1939, showed two slightly different images, one for the left eye and one for the right, to simulate 3D vision.



Binocular
Binocular vision is the ability to see one object with depth perception, since one eye views from one vantage point and the other eye views from another.

Monster vs Aliens is now available on DVD

Life-like movies use an optical trick for 3D

How 3D mo

Movies in 3D – such as the upcoming *Avatar* – make the cinema come alive with objects and characters that seem to have life and limb. Yet, beyond the simple 3D goggles we've worn at the theatres for decades, the visual trickery is a technical marvel – and one that your own body does every day.

In fact, your eyes are perfectly situated for depth perception at about three inches apart. Objects in the real world, viewed from a metre or so away, have a realistic look because your left eye sees one vantage point, your right eye sees the other side, and your mind combines them into one (objects beyond several meters look two-dimensional). The optical trick, which we perceive naturally in the real world, is easy to duplicate in movies and games by shifting the left and right eye images slightly. The hard part is making 3D objects actually look real without giving you a headache or making you feel woozy.

The shifting that occurs for 3D images – one for the left eye, one for the right eye – requires directors to shoot with two cameras,

5 TOP FACTS 3D MOVIES

Toy Story in 3D
1 This autumn, Pixar released *Toy Story* in 3D, with *Toy Story 2* due to do the same in early 2010, and *Toy Story 3* will also get the 3D treatment.

Avatar movie
2 One of the most highly anticipated movies of the year is James Cameron's *Avatar*, which uses polarisation for a 3D effect.

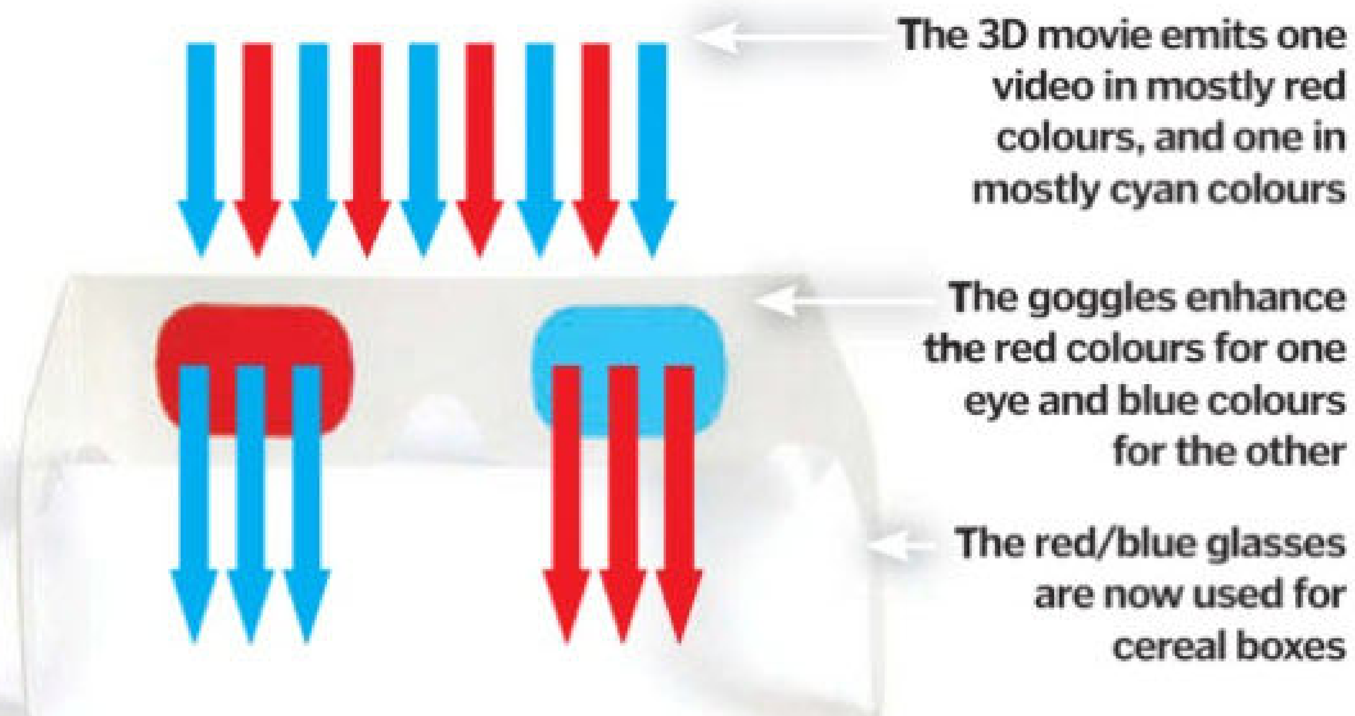
Lenticular 3D technique
3 Lenticular 3D techniques require that you keep your head perfectly still... something which can prove slightly challenging for some!

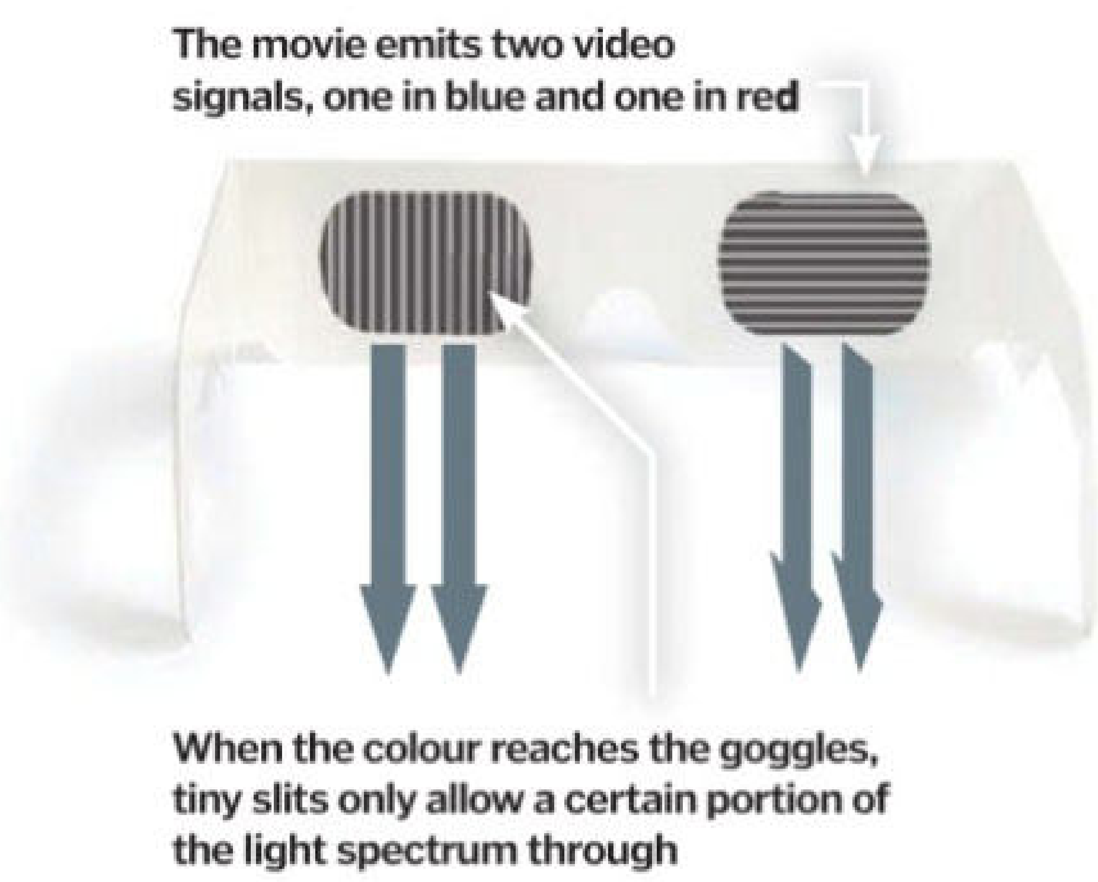
Bah, humbug
4 Disney's next movie to feel the 3D force will be the festive release of the classic *A Christmas Carol* starring Jim Carrey.

The big screen
5 The largest cinema screen in the world is the LG IMAX theatre in Darling Harbour, Sydney. It measures more than 1,015 square metres!

Red/green or red/blue

The red/blue glasses you see for many older 3D movies – such as the *Spy Kids 3D* film from a few years ago – are still common, but the polarisation method is a bit more realistic. With the red/blue goggles (which actually use red and cyan), one eye perceives the red colours of a scene and your other eye perceives the cyan colours, which are slightly offset from each other. You perceive them as one combined image.





Polarising

Polarisation – used as a 3D movie technique – works the same as the polarisation used on sunglasses. Tiny, microscopic slits are arranged perpendicular to the light emitted from the movie projector so that only a portion of the movie (such as the colour green for one eye and red for the other) is allowed to pass through. With 3D polarisation, the slits let a portion of the movie through for the left eye and a second portion for the right eye. Polarisation, according to Rob Hummel, was invented in the 1800s using mineral crystals on goggles that looked like heavy opera glasses.

3D monitors

A 3D monitor is distinct from the other methods used for displaying 3D movies, although the technique (showing an image for the left and right eye separately) is the same. With a 3D monitor, the video signal is displayed for 30 frames of a 60Hz video signal for the left eye, and then 30 frames for the right eye.

IMAX 3D

Polarisation is used for IMAX movies in 3D as well, but the 3D effect is enhanced by using two video projectors in the theatre, one for the left eye and one for the right. In addition, the goggles used for IMAX movies used electric signals to shutter off the left and right eye for the portion of the video that is being shown for the opposite eye, increasing the depth perception and the 3D effect.

Types of 3D explained

3D exists in four different guises

vies are made

positioned next to each other. They then shift the recorded video slightly. To perceive the 3D effect, you need goggles that help you perceive the flat image in the same way your brain blends left and right images into one. Of course, there are several ways to make this work, such as polarisation (which lets only a specific light spectrum through a lens) and by showing left and right portions of interlaced video (the pixels on a computer monitor).

"3D is a stereo-optical illusion that mimics what we do naturally by showing two separate images, one for the left eye and one for the right," says Rob Hummel, the CEO of Prime Focus Post Production who has held posts at Technicolor and Walt Disney Studios.

The only real challenges with 3D, which might be resolved in the next decade, are that the flying objects tend to make us sick when viewed for long periods, there is no way to send the left and right video to your eyes unless you wear goggles, and existing video – even movies filmed this year – cannot be converted to 3D easily.

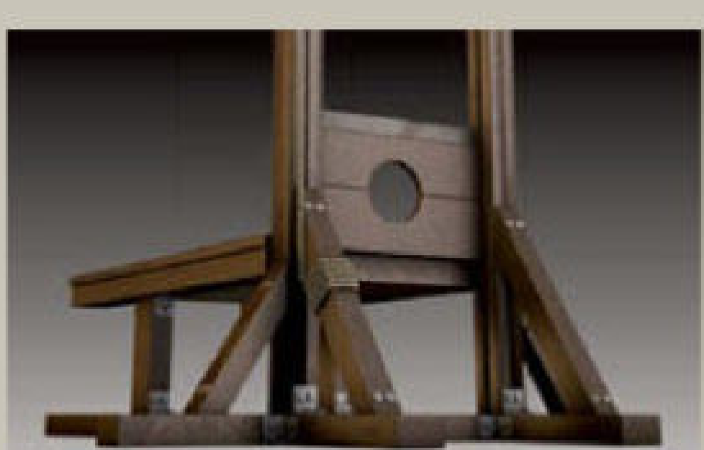
Learn more

If you want to find a list of all the 3D movies released or forthcoming, take a look at **www.3dmovielist.com** and visit the illustrated list section. It contains an exhaustive list of movies along with pictures and information.

The defensive duties of a castle

This month in **History**

The History section is the place to find out fascinating facts about how things worked in days gone by. A personal favourite from this launch issue sees us explain the grim workings of madame guillotine, the machine that gruesomely claimed the life of many a French aristocrat during the French revolution and claimed its last victim as surprisingly recently as 1977.



78 Guillotines

78 Mummification

80 How heraldry worked

Inside a medieval castle

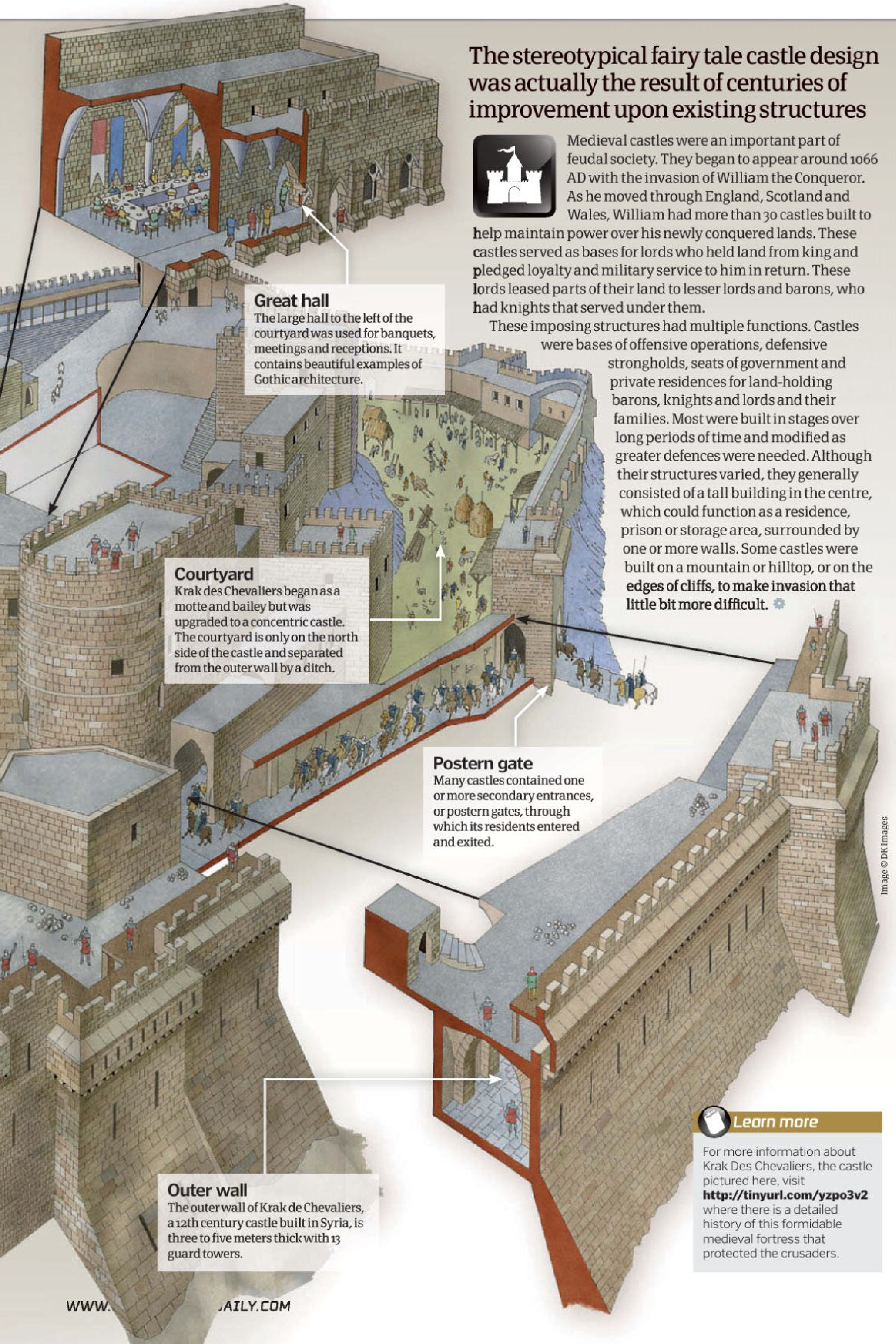
Why did castles die-out?

Gunpowder came into use in the 13th Century and spelled the end of castles as military strongholds. Thick, high stone walls could withstand the forces of catapults and trebuchets, but did not hold us as well against cannon fire. Some castles functioned solely as private residences for nobles and were built on aesthetic principles. Defensive castles evolved into castle-fortresses, with low-angled walls and rounded towers.

DID YOU KNOW?

The world's largest castle...

According to Guinness World Records, the world's largest castle is Prague Castle. Built around 880 CE by Prince BoĐivoj, Prague Castle is actually a complex of towers, palaces and other buildings in various architectural styles. It covers nearly 70,000 square metres.



The stereotypical fairy tale castle design was actually the result of centuries of improvement upon existing structures

Medieval castles were an important part of feudal society. They began to appear around 1066 AD with the invasion of William the Conqueror. As he moved through England, Scotland and Wales, William had more than 30 castles built to help maintain power over his newly conquered lands. These castles served as bases for lords who held land from king and pledged loyalty and military service to him in return. These lords leased parts of their land to lesser lords and barons, who had knights that served under them.

These imposing structures had multiple functions. Castles were bases of offensive operations, defensive strongholds, seats of government and private residences for land-holding barons, knights and lords and their families. Most were built in stages over long periods of time and modified as greater defences were needed. Although their structures varied, they generally consisted of a tall building in the centre, which could function as a residence, prison or storage area, surrounded by one or more walls. Some castles were built on a mountain or hilltop, or on the edges of cliffs, to make invasion that little bit more difficult.

Great hall
The large hall to the left of the courtyard was used for banquets, meetings and receptions. It contains beautiful examples of Gothic architecture.

Courtyard
Krak des Chevaliers began as a motte and bailey but was upgraded to a concentric castle. The courtyard is only on the north side of the castle and separated from the outer wall by a ditch.

Postern gate
Many castles contained one or more secondary entrances, or postern gates, through which its residents entered and exited.

Outer wall
The outer wall of Krak de Chevaliers, a 12th century castle built in Syria, is three to five meters thick with 13 guard towers.

Learn more

For more information about Krak Des Chevaliers, the castle pictured here, visit **http://tinyurl.com/yzpo3v2** where there is a detailed history of this formidable medieval fortress that protected the crusaders.

The guillotine was the official method of execution in France until 1981

Meet Madame Guillotine

During the French Revolution, anatomy professor Joseph-Ignace Guillotin proposed that capital punishment in France should be carried out by decapitation on people of all classes because it was the most humane method available. Dr Antoine Louis of the Academy of Surgery designed the machine that came to be known as the guillotine after pointing out that beheading by sword was highly impractical.

The guillotine consists of a wooden frame with an angled blade that runs along grooves. After the executioner raises the weighed blade with a rope, the condemned is placed on a platform with his or her head in a round wooden frame called a lunette. The executioner lets go of the rope, allowing the blade to drop. Until abolishment of the death penalty in 1981, France continued to use the guillotine as its method of execution. Although still legal in a few other countries, the guillotine has not been used since.

"Beheading by sword was impractical"

DID YOU KNOW? Numerous witnesses have reported heads moving, speaking and blinking for a few seconds after decapitation.

The forgotten art of mummification

Mummies have been found in many parts of the world, but Egyptian mummies are the most well-known due to their distinctive appearance and unique embalming process


© 2005 David Monniaux

Ancient Egyptians used to bury their dead directly in the hot sand, which dried and preserved them somewhat. When they began using caskets, the bodies decayed instead. Around 2600 BCE, Egyptians began experimenting with a way to preserve their ancestors. They learned that bodies decayed from the inside out, starting with their organs. Embalmers perfected a process by which the organs were removed and the body dried prior to burial. This practice, known as mummification, was used for nearly 3,000 years.

Mummification was an expensive process and could take up to 70 days to complete. The embalmers worked in open tents, out in the desert and away from the general population. After washing the body, they removed the brain from the skull. In order to get into the brain cavity, embalmers put a chisel up the body's nose and hit it with a hammer to crack through the bone. Then, they inserted a long hook to pull out brain matter.

After cutting a slit in the left side of the body, embalmers removed the abdominal organs. They were washed, wrapped in linen and packed in jars. Natron, a naturally occurring salt, was added as a drying agent. The body was rinsed with wine and filled with incense and natron, then covered with more natron. A slanted table allowed fluids to drip from the body as it dried while guards kept away scavengers. Once the body was dry, embalmers wrapped it in linen strips in several stages and coated it with resin. The linen helped keep the body together and prevented moisture from entering. A rigid scaffold was then fitted over the body and a funeral mask attached to the face. Finally, the completed mummy was placed into a container decorated to look like a person, called a suhet.


An extreme way of wrapping up warm for winter

THE STATS T-REX

One T-Rex weighed the same as... 1 x **Bull elephant** 10 x **Horses** 1 x **Double decker bus** 2 x **Small helicopters**

How T-rex hunted prey

The T-Rex may have been one of the largest meat-eating dinosaurs, but it might not have been a predator at all

Tyrannosaurus rex – from Greek and Latin words meaning 'tyrant', 'lizard' and 'king' – was one of the largest carnivorous dinosaurs to walk the earth. It lived about 85 to 65 million years ago, in lightly forested North American river valleys and plains. The T-Rex stood more than four metres tall and 12 metres long, weighing in at five to seven metric tons. Some fossil evidence shows that the female T-Rex may have been the larger of the sexes, although there's no way to know for sure. Its banana-shaped, serrated teeth gripped flesh and its massive jaw crushed bones as it downed more than 200 kilos of meat in one gulp. Likely prey included the Triceratops horridus and the Torosaurus, each about the size of an elephant.

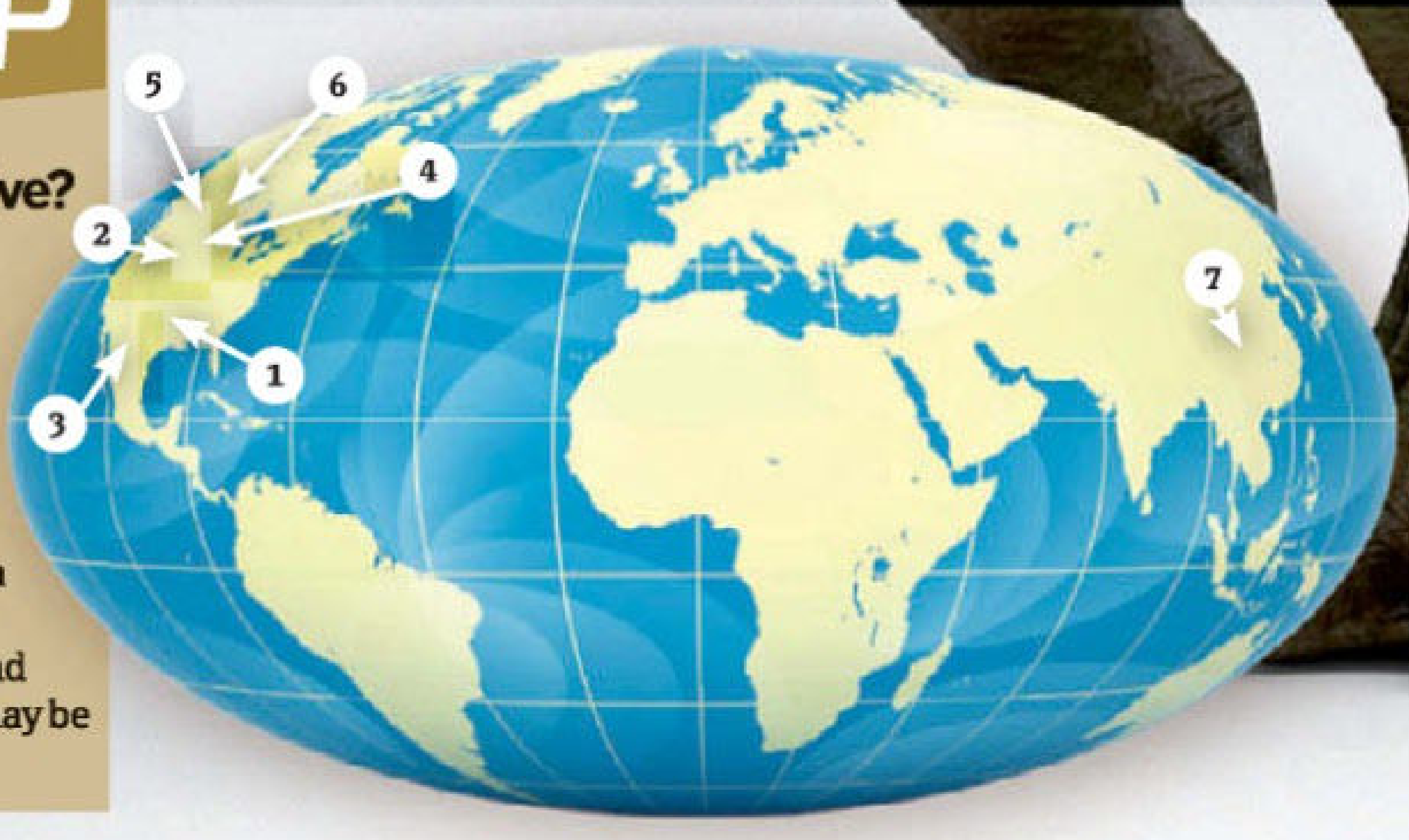
There have been several nearly complete Tyrannosaurus rex skeletons found since the first bones were discovered in 1894, some of which included soft tissue. From these, palaeontologists have learned that the T-Rex had a lot of bird-like traits. It likely had a one-way air sac system that kept its lungs constantly full of fresh air, hollow bones to lighten its body weight, and binocular, colour sight. It also had a wishbone, or furcula. Some palaeontologists believe that our assumptions of scaly, lizard-like skin might not be entirely accurate and that T-Rex could've even had feathers.

Controversy about the T-Rex centres on whether it was a predator or a scavenger, as well as whether it moved slowly or quickly. Many palaeontologists believe that the Tyrannosaurus rex was strictly a predator, but those who question this assumption point to its short, weak arms with two-fingered hands, large legs suited for walking distances and a strongly developed sense of smell. These seem more in line with what we know of scavengers rather than predators. Others argue that muscle scars found on skeletons show that the T-Rex had strong arms. They also believe that their binocular sight and hollow bones indicate a faster-moving predator. However, predators today will sometimes scavenge if fresh prey isn't around, so T-Rex could've actually been both.

ON THE MAP

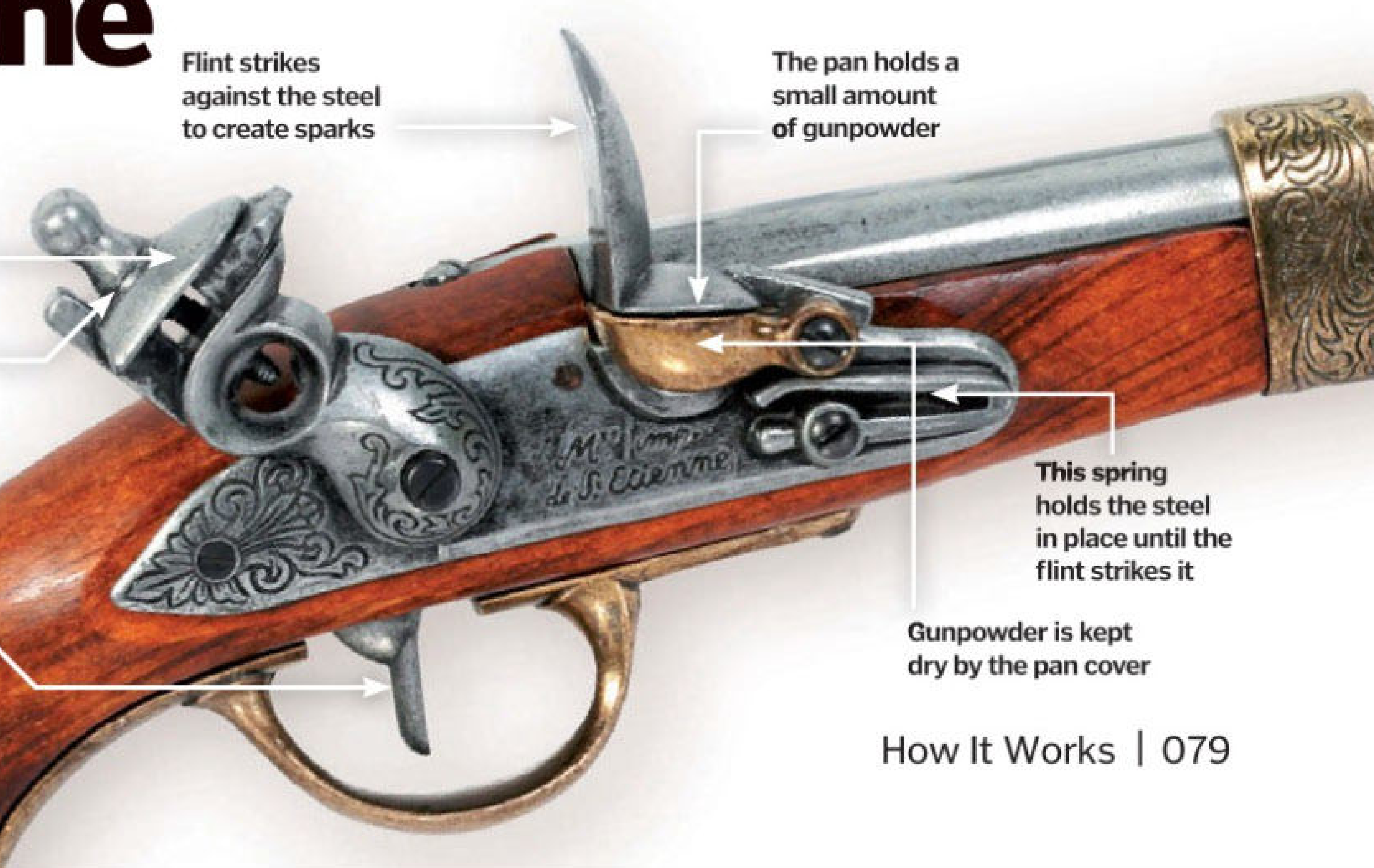
Where did T-Rex live?
Western North America, fossils found in:

1. Montana
2. Wyoming
3. New Mexico
4. South Dakota
5. Alberta, Canada
6. Saskatchewan, Canada
7. possibly Mongolia (Tarbosaurus bataar found there is closely related, may be same genus)



The physics of the flintlock pistol

First developed in the 16th Century, the flintlock pistol was a revolution, changing the way we waged war and its impressive mechanism was used by armies for over 200 years



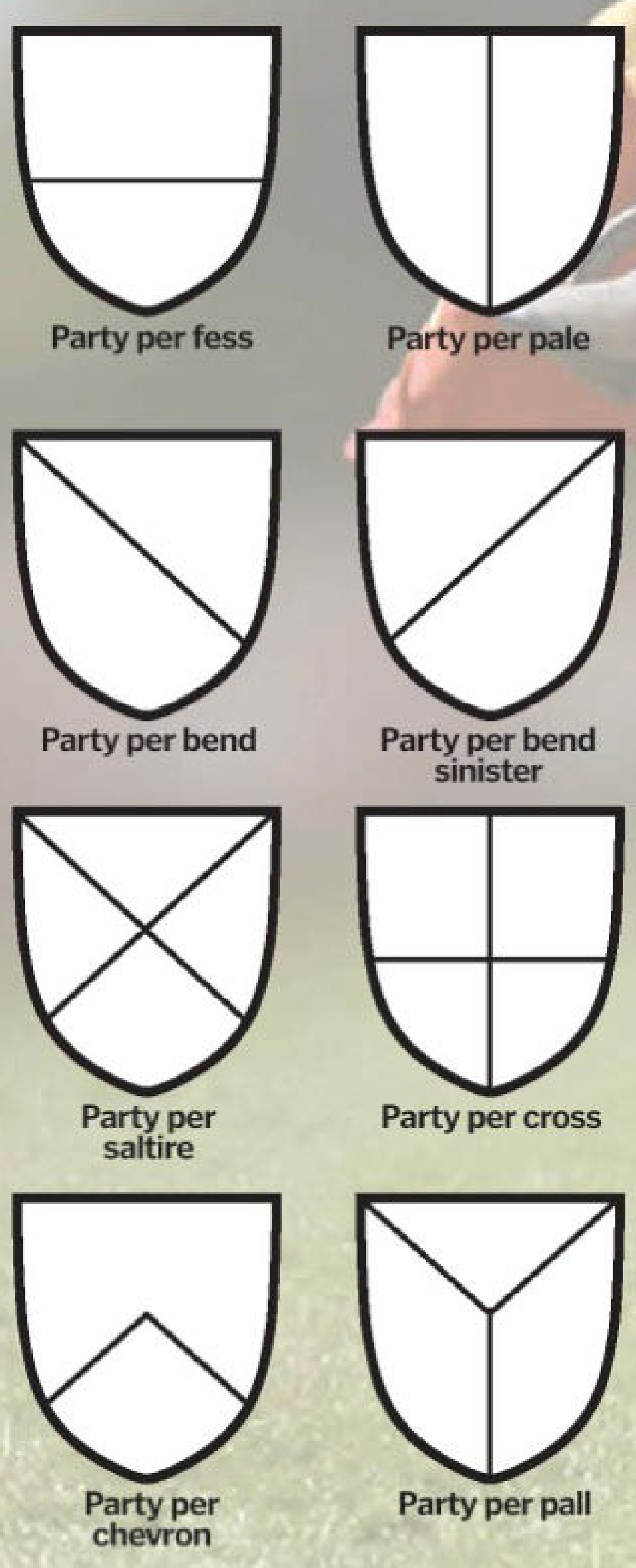
Catalonian flintlock pistol, circa 1711

He

Divisions of the field

The shield may be sectioned into portions called divisions. Divisions may be used to marshall (combine different coats of arms) or difference (distinguish one coat of arms from another). Marshalling may consist of dimidiation, dividing two coats of arms in half and splicing them together in the middle. Combining was also done by putting two coats of arms on one shield. As with ordinaries, divisions of the field can also vary widely.

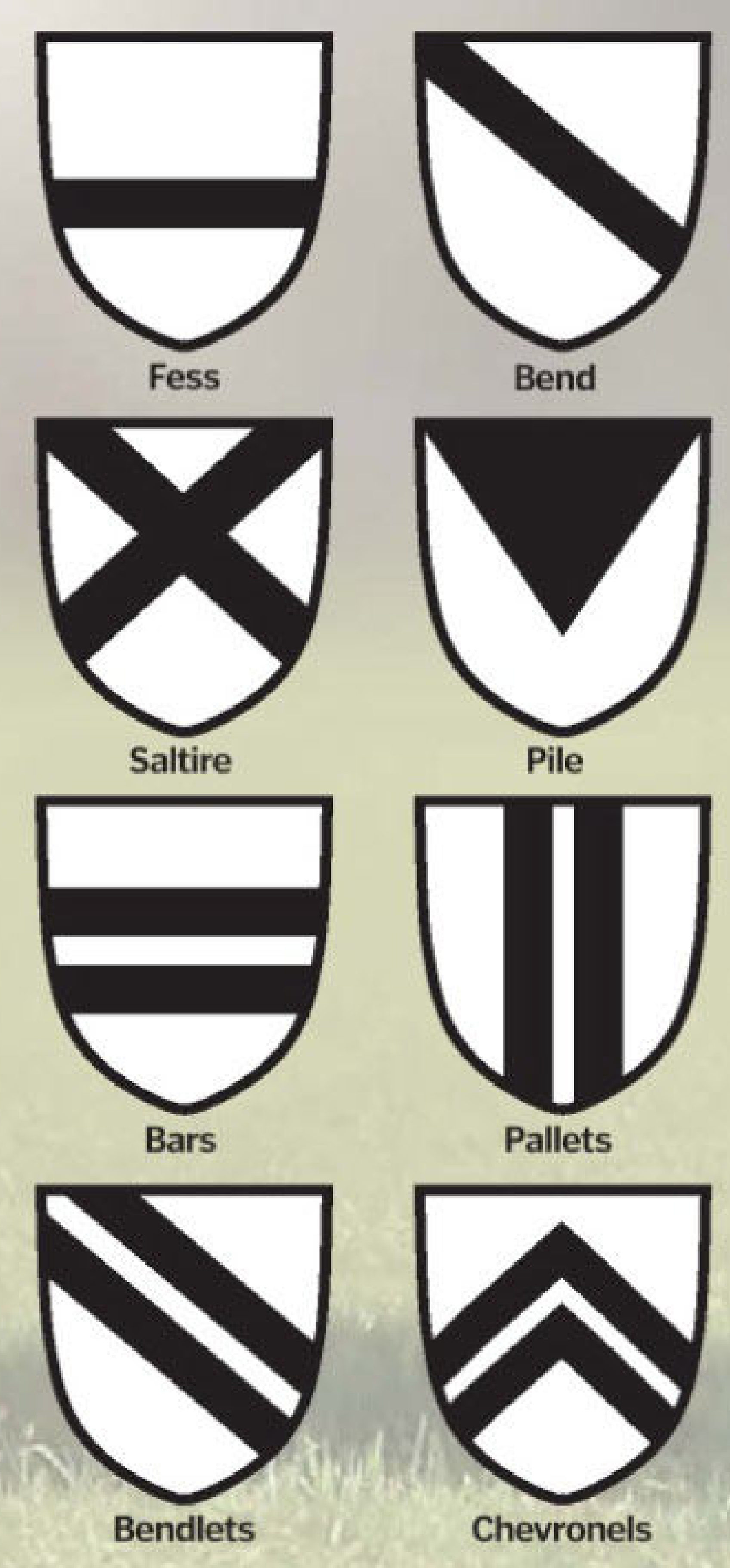
When a division is done along an ordinary, it is known as a party. Shields divided horizontally are party per fess. Party per pale is halved vertically, while party per bend is divided diagonally from upper left to lower right. A shield can also be party per bend sinister, meaning that it is divided diagonally from upper right to lower left. Shields divided by a diagonal x are party per saltire, but quarterly or party per cross is a traditional cross division. Party per pall divides the shield into a y-shape, and the party per chevron divides the shield according to a chevron.



Ordinary

Ordinaries are basic geometric charges bordered by straight lines. There are several agreed-upon ordinaries as well as variations.

A fess is a horizontal band that runs across the centre of the shield, taking up one third to one fifth. Bars are a diminutive of the fess, with two narrow horizontal bands. When a band runs diagonally from the upper left to the lower right of the shield, it is called a bend. One variation is the bendlet, with two narrow diagonal bands. If the band is vertical, it is called a pale. A pallet has two vertical bands. The saltire is an x-shaped cross, also known as St Andrew's cross, while a chevron is a v-shaped line pointing upwards. Generally the lines meet at a right angle, but it may be diminished (with an obtuse angle) or enhanced (with an acute angle). Finally, an ordinary depicting a triangle, flat side at the top and point side down, is a pile.



DID YOU KNOW?

It's not a family crest

Coats of arms belong to individuals, not family surnames, so searching databases may turn up many different coats of arms.

eraldry explained

Although it's often believed that coats of arms were for nobility only, people from all walks of life bore them during medieval times

Crest
The crest is a symbol, often an animal or the head of an animal, indicating heredity.

Helm
The helm or helmet joins the crest to the shield, and its style and colour designates the bearer's rank.

Coronet
A person entitled to wear a coronet typically displays one to identify himself in his coat of arms.

Field
The field is the shield's background, either solid or patterned, which may be divided into sections.

Ordinaries
An ordinary is a basic geometric design consisting of straight lines that runs from side to side or from top to bottom.

Motto
The motto would typically be a saying – either a philosophy or a battle cry – historically associated with a family.

Supporters
These are animals, people or other objects placed on either side of the shield. Their use is often strictly governed.

Shields
The actual shape of the shield could change over time and varied according to the artist's whim. However, individual elements of the shield held important significance.

Dissecting a coat of arms

Each element on a coat of arms holds a specific meaning, and rules govern how and where each symbol and colour is used

Heraldry is the art of creating, displaying and describing a coat of arms. These designs, also known as armorial bearings or armorial achievements, are used by a particular person or group of people to represent themselves in various ways. Coats of arms essentially combined designations already in use on insignias, seals, emblems, banners and shields. Through different elements a coat of arms does three different things: it displays ownership of land, identifies the holder's family and identifies the individual.

It is unknown exactly when coats of arms were adopted, but most historians believe that they appeared sometime in the late 11th Century to early 12th Century. Knights may have used coats of arms to identify themselves, as they would otherwise not be recognisable due to their helmets. By the 14th Century, people of all walks of life, as well as religious communities and corporations, could assume and bear coats of arms. They simply had to avoid taking up coats of arms that belonged to another person, family or group within their area.

In the 16th Century, several European countries such as England and France began to pass laws of heraldry or the Law of Arms. These laws state that coats of arms can only be borne if you are granted the right by the State or the Crown, or if you can prove an ancestral right to do so. Many countries today have Chief Heralds as well as special courts that grant arms and rule on conflicts.

Tinctures – describing the coat of arms

Tinctures are the colours and patterns used to formally describe, or emblazon, a coat of arms. Metals are the light tinctures, gold and silver. Officially known by Or and argent, the metals can be represented by yellow or white respectively. In the absence of any colour at all – such as in engravings – Or is instead represented by small black dots on a white background.

There are five colours: blue, red, purple, black and green. Respectively their names are azure, gules, purpure, sable and vert. They are also represented by differently oriented lines. Furs are the final category of tincture. The furs are ermine, ermines, erminois, pean, vair, counter-vair, potent and counter-potent. Ermine is designed to depict the winter coat of the stoat, a small weasel, which is white with a black tail. Erminois and pean are variations of ermine. Vair represents the fur of a grey and white squirrel, with ounter-vair as a variant. Potent and counter-potent are similar to vair but with a t-shaped bell. Because coats of arms were used for identification, it was important to adhere to the Rule of Tincture. This rule decrees that metal cannot be put next to metal, or colour next to colour.

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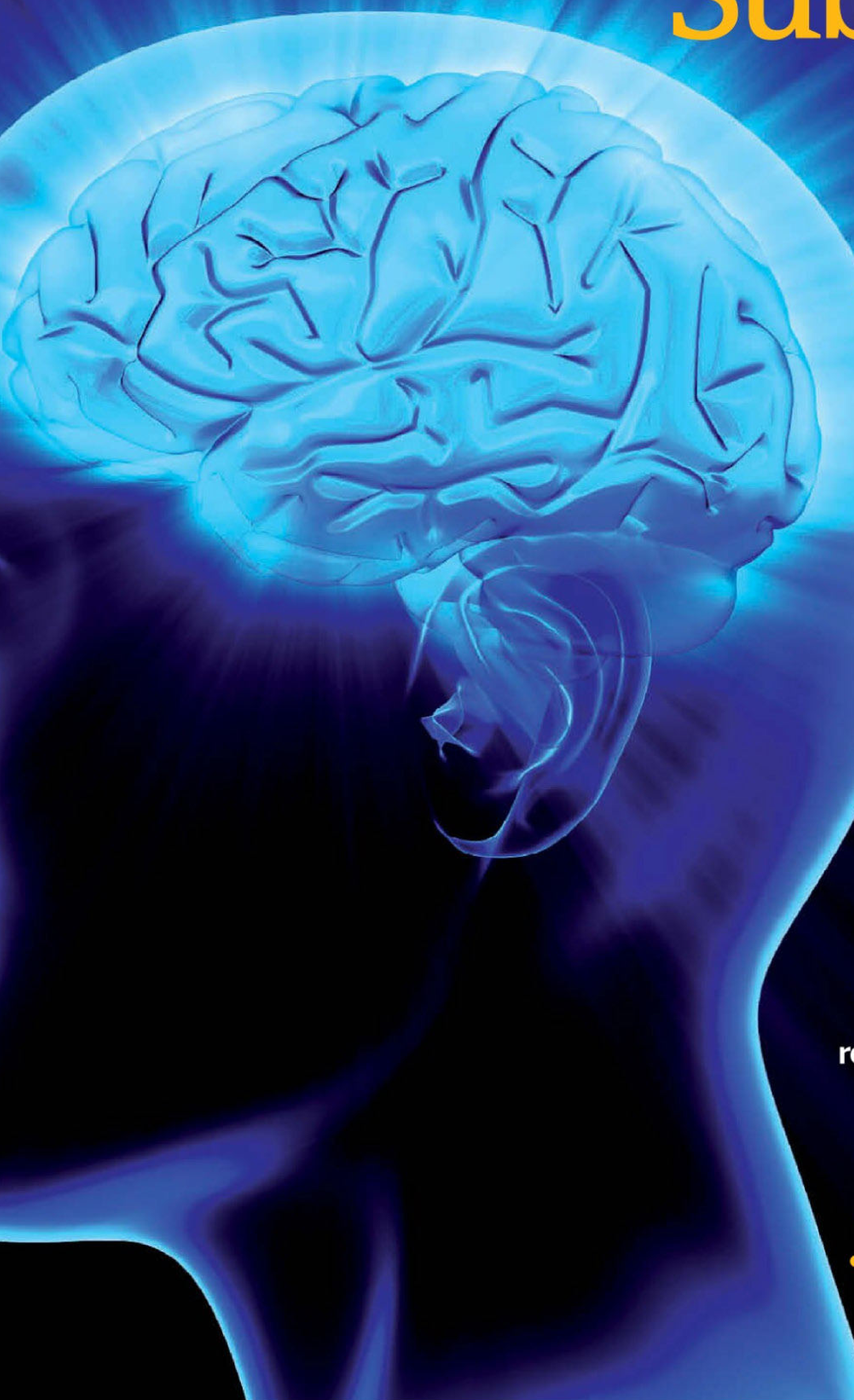

BRAIN DUMP

Because enquiring minds want to know...

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The How it Works experts are ready and waiting to answer your questions so fire them off to... howitworks@imagine-publishing.co.uk

HOW IT WORKS EXPERTS

How It Works is proud to welcome the curators and explainers from the National Science Museum to the Braindump panel

Doug Millard
Senior Curator of Space Technology

Doug Millard is Senior Curator of Space Technology at the Science Museum. Doug has produced many space exhibitions, written articles, papers and books including a history of the Black Arrow satellite launch vehicle and its engines, lectured widely and appeared on television and radio. He is currently researching the history of the Apollo 10 command module.

Rob Skitmore
Assistant Curator of Technology

Rob Skitmore is Assistant Curator of Technology at the Science Museum. With a background in IT, Rob has worked on exhibitions spanning diverse topics in the history of technology including time measurement, genetic modification and post-war British technology. Rob's interests lie in gadgets, robotics and computer technology.

Rik Sargent
Science Museum Explainer

Rik is an Explainer in the Science Museum's interactive Launchpad gallery. When Rik isn't blowing up stuff or putting people in bubbles he trains the Explainer team in the principles of science.

Imagine that! This is our first issue, so we asked our colleagues at Imagine Publishing to provide us with the questions they've always wanted answers to. Here are the sometimes disturbing results.

"When were we last on the moon and why haven't we been back since?"

Adam Smith

■ Gene Cernan, the last human to walk on the moon, stepped off its dusty surface and onto his spacecraft's ladder in the early morning of 14 December 1972. Seventeen hours later Cernan and Jack Schmitt, his fellow moon walker on the Apollo 17 mission, blasted off from the Sea of Serenity to be reunited with their crew mate Ron Evans, orbiting high above in the command service module. Cernan had said, as he climbed the ladder, that he believed it would not be too long before people once again walked on the moon.

Well, almost 40 years on and we have yet to return. Why is this? Put crudely it is because, for those people who would have made the decision to return, there has been no need too. Project Apollo happened because President Kennedy and the US Congress wanted it to; a demonstration of American scientific and technological capability to surpass that achieved by the Soviet Union with its Sputnik and cosmonaut programs. Once Neil Armstrong had stepped onto the Moon in 1969 and been 'returned safely to the Earth', Kennedy's objective had been achieved – the space race had been won – and the political will to maintain a multi-billion dollar manned moon program evaporated. Will we return? Possibly, but whoever gives the decision will have to be happy with the huge price tag it brings with it.

Doug Millard

What is jailbreaking an iPhone?

Helen Laidlaw,

■ Apple ensures the quality of software available for the iPhone by screening before release through the built-in App Store. There are other applications that will run on an iPhone but haven't made it into the App Store. There are several ways you can get round the restrictions and install third-party software. The phone is then said to be jailbroken.

Rob Skitmore

The speed at which the galaxy is moving is almost incomprehensible

"Exactly how fast is our galaxy moving?"

Dan Howdle

Until the 20th Century it would have been virtually impossible to reach any sensible figure for the speed with which our galaxy – the Milky Way – is travelling through space. Many scientists would not have presumed the galaxy to be moving at all. This all changed, however, when the universe was shown to be expanding from a huge explosion or big bang of creation, with the Milky Way and the billions of other galaxies seemingly spreading out across the cosmos. But how could we measure this speed of travel for our Milky Way? Scientists in the Forties had predicted that there should be residual evidence of the big bang in the shape of cosmic background radiation infiltrating the whole of space. When this was duly discovered in the Sixties it was used as the frame of reference with which to gauge the rate at which our own galaxy is speeding through the universe. It turns out to be some 1.3 million miles per hour (2.1 million km/hr)!

Doug Millard

What is the difference between hi-def and normal telly?

Jo Cole

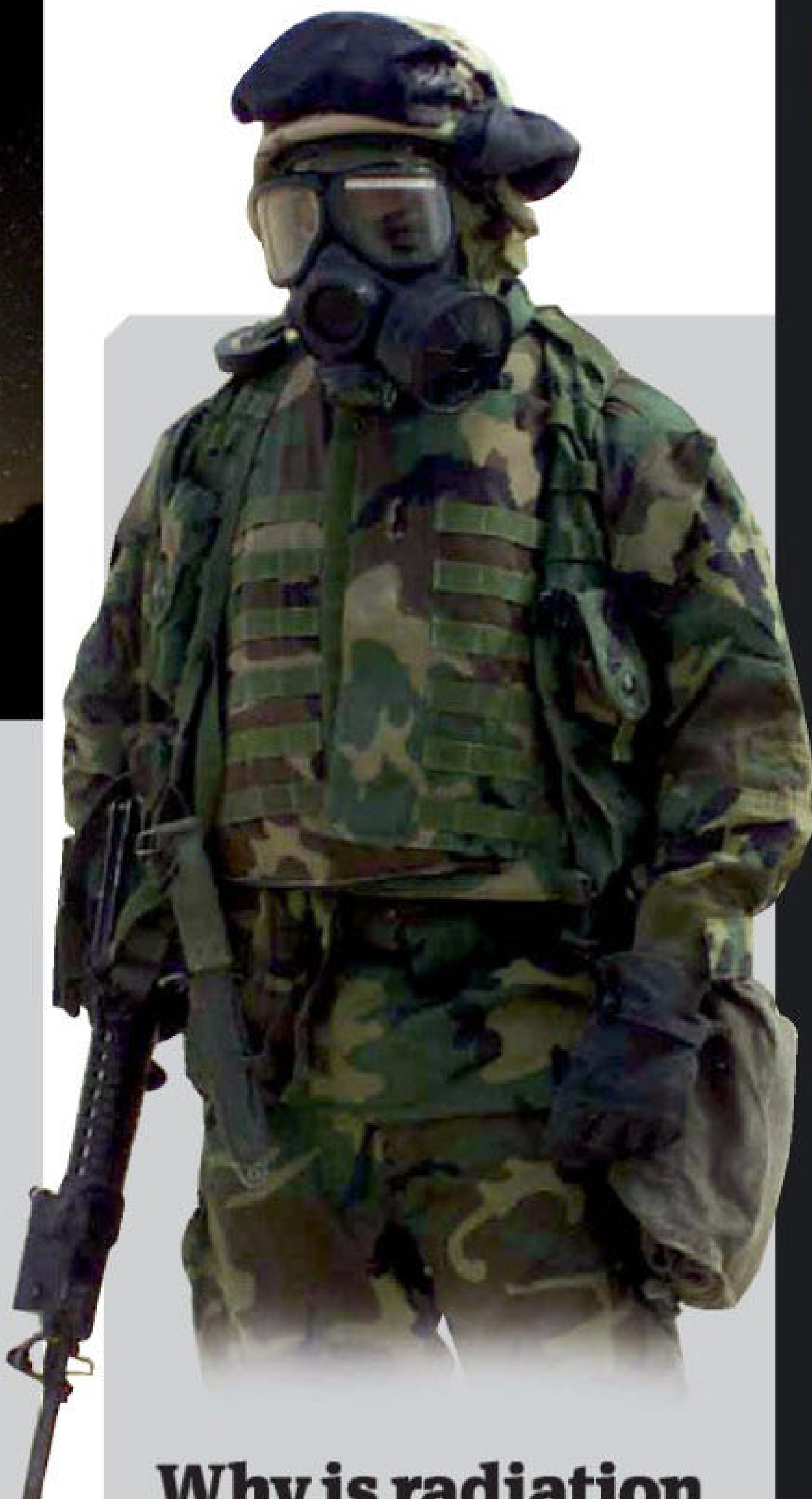
Recently, TV took the biggest leap in picture quality since the arrival of colour back in the Sixties. High definition TVs offer images up to four times as detailed than those by standard TVs.

Standard definition (SDTV) televisions display the picture in a series of interlaced lines. Interlacing is showing alternate lines every other frame. This saves bandwidth but reduces quality. Analogue TV has 625 interlaced lines of which 576 contain picture information.

Broadcasters experimented with analogue HDTV but found it used too much bandwidth to be viable. With the introduction of digital television broadcasting, digital compression can be used to shrink the HDTV signal to a reasonable size.

The output of modern TVs is described using numbers. For example, 720p means 720 progressively scanned lines. That's much more detail than 576i or SDTV and even better pictures can be had with TVs that can display 1080i (i for interlaced) or even 1080p (p standing for progressive).

Rob Skitmore



Why is radiation so dangerous?

Stuart Dixon

There are many different types of radiation, for example visible light is a form of radiation. Some are more harmful than others. For example, there are on average 15,000 radioactive particles travelling through your body every second!

With all this radiation exposure, why aren't we all dying of cancer? Well, it is not the amount of radiation which you come into contact with, as every single one of these particles has the potential to cause cancer, it's just the probability of that occurring is about one in 30 quadrillion!

Only approximately one per cent of fatal human cancer is caused by these 30 trillion radioactive particles which pass through our bodies in a typical lifetime.

Ionising radiation has the energy to detach electrons from their associated atoms, therefore causing the atom to become positively charged. These charged particles are referred to as radicals and are highly reactive due to their unstable nature.

Radicals are very important for certain processes in the body such as the killing of bacteria. However, many unwanted effects such as mutation of cells can be a problem. Scientists have found lots of evidence to suggest that these radicals cause mutations in cells which can give rise to cancer.

Rik Sargent

sciencemuseum

What's on at the Science Museum?

Prove It! All the evidence you need to believe in climate change

Opens 22 October FREE
Explore the scientific evidence that human activity is behind climate change.

Measuring Time

From 13 October FREE
The newly refurbished Measuring Time gallery displays one of the finest collections of clocks and watches in Britain.

Force Field – the ultimate multi-sensory experience

Charges apply
See, hear, feel and even smell what it would be like to venture into space with a ride in the Science Museum's extraordinary new multi-sensory experience.

Cosmos and Culture: how astronomy has shaped our world

Until 2010 FREE
Cosmos & Culture traces 400 years of telescope technologies, explores our changing perceptions of our place in the cosmos, and examines the role astronomy has played in our everyday lives.

Centenary talks

Talks cost £6 per person.
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The Age Of Wonder

2 November 2009, 19.30 – 21.00 (doors open at 19.00)
Take an in-depth look at the relationship between poets and scientists during the Romantic era with Dr Richard Holmes, author of the bestselling book *The Age Of Wonder*.

Living in a digital world

23 November 2009, 19.30 – 21.00 (doors open at 19.00)
Dame Wendy Hall, Professor of Computer Science at the University of Southampton, explains what it will mean to be a digital citizen in the future.

For further information visit the what's on section at www.sciencemuseum.org.uk/centenary.

"How much force is generated by Niagara Falls?"

Jonathan Gordon

Niagara Falls is comprised of two major sections separated by Goat Island. They are exceptionally wide and due to this they allow approximately 1,833.33 cubic metres of water to pass over the edge per second.

To find out how much force this will generate we can use force = mass x acceleration.

The mass of one cubic metre of water is roughly 1,000kg.

To find the mass of 1,833.33 cubic metres of water: 1,000 x 1,833.33 = 1,833,333.330kg

F=ma

a = 9.81 metres per second squared

Therefore, the force which this water exerts = 1,833,333.330 x 9.81 = 17,985,000 newtons every second!

It must be noted that this is the force which would be experienced if all of this force could be concentrated on an infinitesimal point. It is not the force you would experience per second if you stood under Niagara Falls, as you would only represent a tiny area of that which the water is hitting.

Rik Sargent

Which way does water really drain at the equator?

April Madden

The Coriolis effect is the name given to the inertial force experienced by liquids and gases due to the rotation of the Earth. It explains why cyclones rotate clockwise in the southern hemisphere and anticlockwise in the northern.

Factors that go into deciding which way water will go down a plughole are numerous. The Coriolis effect often gets wrongly associated with this type of drainage and the truth is that it is too small a force to have any noticeable impact.

The direction which water drains at the equator is much more dependent on the geometry of the container and the direction which that water was added to the container. The motion of water molecules at any given instant will also affect this.

In other words, there is no specific direction water will drain at the equator as the variables are too numerous.

Rik Sargent

Do dogs see in black and white and how do we know?

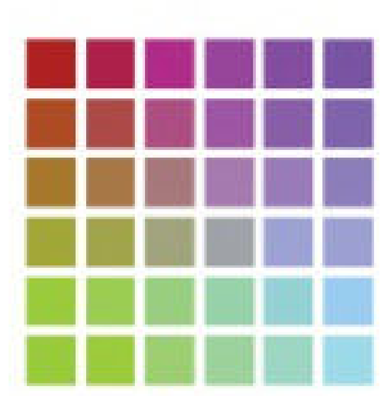
Natalie Johnson,

Contrary to popular belief, dogs do have some colour vision though this is undoubtedly different to the vision of humans.

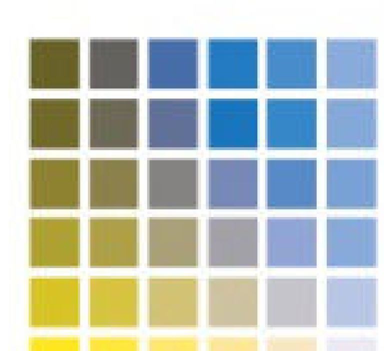
In the human eye there are two types of photoreceptors called rods and cones. Rods help us to determine differences in brightness and darkness where cones are sensitive to colour. We have three types of cones: some are sensitive to red light, some are sensitive to green and some to blue. Dogs have more rods than humans and less cones. Rods need less light to work and this accounts for dogs having better night vision than humans. Humans rely more on cones and the differences in wavelength are harder to detect when there is less light, hence we don't see very well in the dark.

Dogs are said to have dichromatic vision; they can only see a part of the range of colours which are in our visible spectrum. It is thought that dogs can see different shades of yellow and blue as they have cones which correspond to being able to detect these wavelengths of light. Whether their yellow is the same as yours or mine is a different matter.

Rik Sargent



HUMAN COLOUR RANGE EXAMPLE



DOG COLOUR RANGE EXAMPLE

If freezing something causes it to lose energy, why does ice expand and have the energy to burst pipes?

Mark Kendrick

Water is different to most other substances as upon turning into ice, its volume expands by roughly nine per cent causing it to become less dense. This is due to nature of the bonds between the molecules and the shape of those molecules.

Upon changing state, a substance needs to absorb or release a certain amount of energy to undergo the phase transition. For a solid turning into a liquid, this energy is needed to break the bonds in the solid therefore needs to be absorbed by the system. For a liquid turning into a solid, this energy is released as the bonds form.

For 1kg of water at freezing point to change into ice, it must give off 333.55kJ to the surroundings, just to undergo the phase transition. This large amount of energy is normally given off as heat, which means it gives the molecules in the atmosphere more kinetic energy.

However, if water is contained in a steel pipe at freezing point, the energy given off will be passed on to the molecules and bonds in the pipe, causing the pipe to burst.

Rik Sargent

"Is eating fish really good for your brain?"

Ben Biggs

Yes, especially really oily fish which are rich in omega-3 fatty acids called Eicosapentaenoic acid (EPA) and Docosahexaenoic acid (DHA). Omega-3 is vital for brain growth/development, functioning and production of neurotransmitter – the chemicals which relay signals between the brain cells.

The human body cannot easily synthesise these fatty acids and so a constant supply is very important. Just like a healthy machine your brain needs oil, and this comes in the form of omega-3.

Rik Sargent

Why don't whales get the bends?

Dan Howdle

Any scuba diver is aware of the dangers of decompression. When you dive deep in high pressure water, the air which you breathe from your tank will have the same pressure that the water is exerting. If this were not the case then the air wouldn't come out of your tank. At a depth of 33 feet the air pressure is twice that of atmospheric air pressure on land.

High pressure nitrogen from this air dissolves in your bloodstream and water in your body. Anyone who had unscrewed a lid on a shaken fizzy drink bottle knows that bubbles start to fizz up due to the lessening of pressure. The same effect happens to the nitrogen in the bloodstream of a diver if they ascend too quickly.

So, how do whales and other marine mammals handle this tremendous pressure increase? They have adapted to collapse their thoracic cavity, lungs, and alveolar sacs. Whales have very weak and flexible rib cages. While diving, the thoracic cavity is collapsed so no air can get in. When this collapse occurs, there is still air with high nitrogen levels present, in the alveolar sac, which is the site of gas exchange. Marine mammals have adapted to this by creating a cartilage build up in the bronchioles. This allows for alveolar collapse and storage of the air in the bronchioles. This is important because nitrogen is no longer at the site of gas exchange and cannot be absorbed into the body.

Therefore the nitrogen will not fizz in their bloodstream upon ascent, therefore making them effectively immune to the bends.

Rik Sargent

Whales can dive deep without any worries

sciencemuseum

What's on at the Science Museum?

Listening Post

Until 2010 ■ FREE

Listening Post is a critically acclaimed electronic art work, the result of a collaboration between US artist and composer Ben Rubin and statistician and artist Mark Hansen.

Dan Dare and the Birth of Hi-Tech Britain

Until March 2010 ■ FREE

Enjoy a nostalgic hour looking back at an era when Britain was at the forefront of technological innovation after World War II.

Plasticity – 100 years of making plastics

Until January 2010 ■ FREE

This exhibition looks back at Leo Baekeland's world-changing discovery and displays just some of the cornucopia of new plastics and products which followed.

Science Museum IMAX 3D cinema: Now showing

Entry charges apply

Fly Me To The Moon 3D (U)

Get ready to launch into this animated space spectacular and join three curious houseflies that sneak on board the Apollo 11 spaceship mission to embark on a cosmic adventure.

Space Station 3D (U)

Feel the force of a rocket launch, accompany astronauts on a space walk and experience life in zero gravity as you blast off to space.

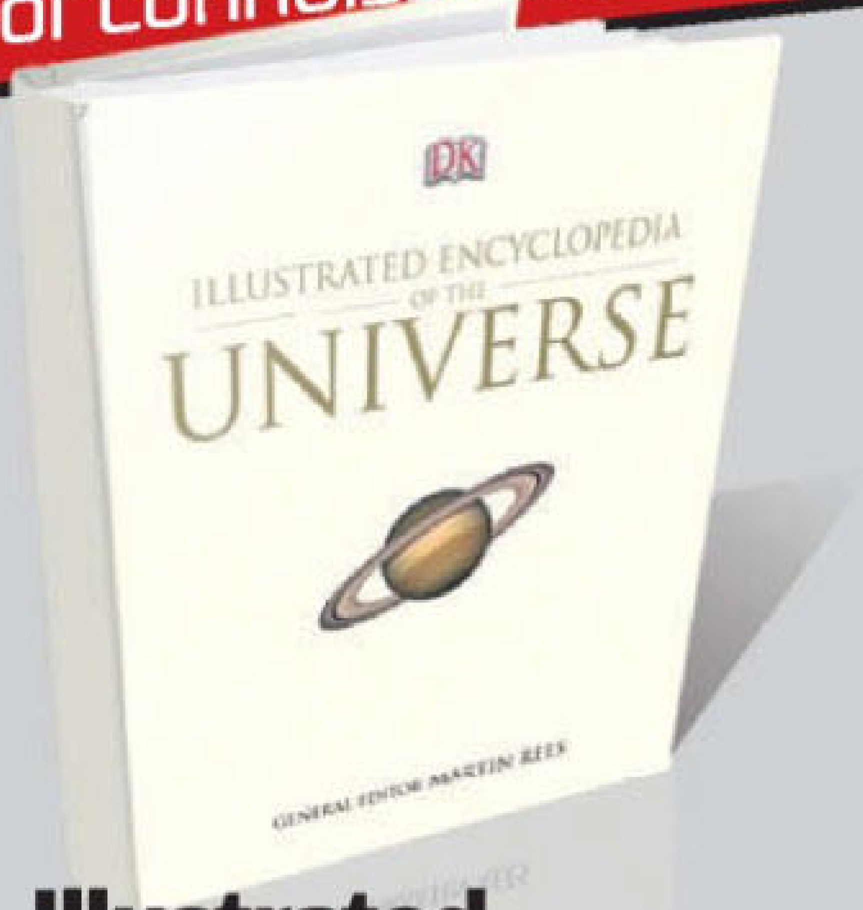
Also showing...

Dinosaurs Alive! 3D (PG)
Sea Monsters 3D (PG)
Deep Sea (PG)

IMAX Booking Line: 0870 870 4771
More info: www.sciencemuseum.org.uk/imax
Prices: £8.00 adults
£6.25 children/concessions

Visit the Museum

Exhibition Road, South Kensington, London SW7 2DD. Open 10am – 6pm every day except 24-26 December. Entry is free, but charges apply for the IMAX 3D Cinema, simulators and some special exhibitions.

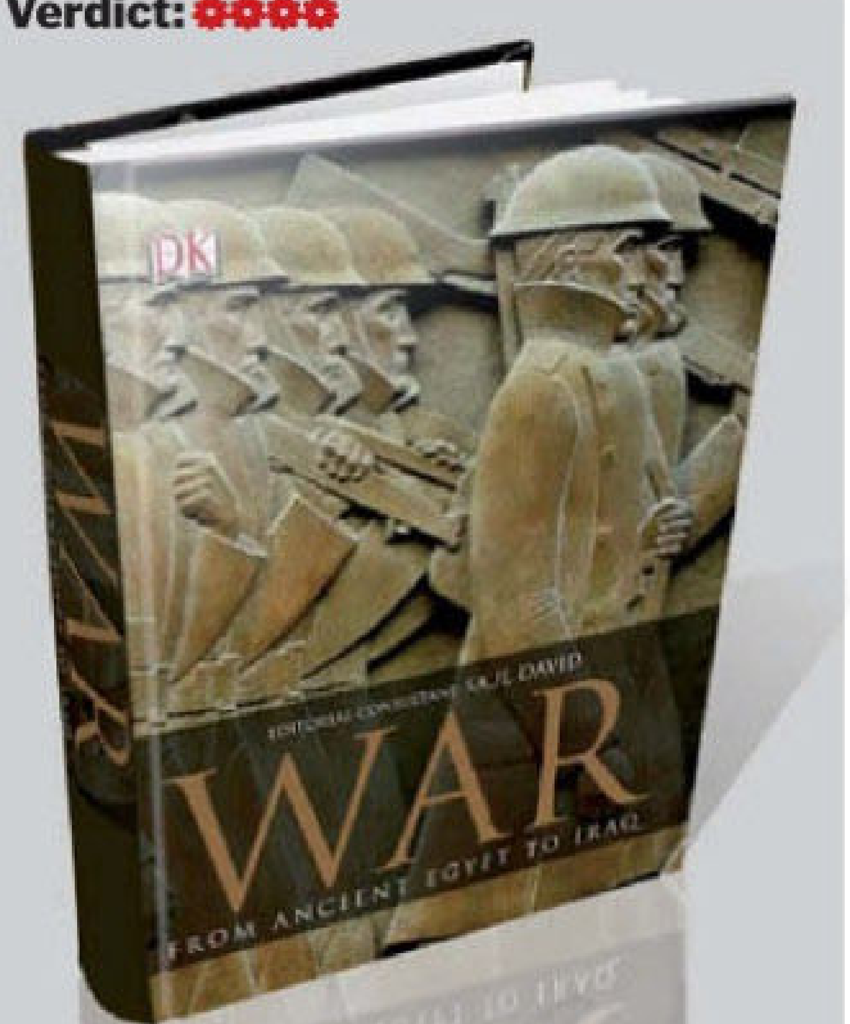


Illustrated Encyclopedia Of The Universe

Price: £22
ISBN: 978-1-4053-3309-2

An encyclopedia by name, flick to any page and a litany of facts ranging from our comparatively mundane solar system to anomalies at the far reaches of the cosmos conspire to raise the profile of this hardback higher than a mere reference tome, while a mesmerising array of photos and illustrations will suck you in faster than a quantum singularity.

Verdict: ★★★★



War: From Ancient Egypt To Iraq

Price: £30
ISBN: 978-1-4053-4133-2

Five millennia split into seven ages of the most prominent conflicts in history are covered here with an admirable attention to fine detail and figures. DK takes this volume a rank up with the inclusion of fascinating personal accounts and small snapshots of the lives of POWs.

Verdict: ★★★★

Move over Patrick Moore…

Sky-Watcher 130P SupaTrak Telescope

Price: £199
Get it from: www.telescopeplanet.co.uk

THE CHANCES ARE that if you're the average person who hasn't dabbled with astronomical pursuits beyond pointing a pair binoculars at the moon when it's looking bright, then the image you conjure in your mind when you think of a telescope will be the refractor variety. This scope places the eyepiece at the opposite end of the objective lens: but this isn't the fundamental design of the Sky-Watcher Explorer 130P. It's a reflector scope that uses a highly polished concave mirror at the base to focus the light of the image and aperture for aperture, it represents the cheapest form available.

Cheap isn't necessarily synonymous with poor quality however. The foundation of the 130P is the 130mm parabolic mirror that provides a surprising clarity of image to the aperture for the price. Mount stability is questionable and though there's no danger of the tripod tipping over, a highly resolved focus will take some time to settle even after a slight knock.

Standard with most telescopes is the motorised tracking system that, once calibrated, allows you to press a button for it to automatically track to a pre-programmed celestial body. Sky-Watcher's SupaTrak technology is also capable of following moving bodies through the sky for minutes on end.

The Sky-watcher 130P includes 10mm and 25mm eyepieces, plus a x2 Barlow lens for magnification power of up x260, a finder scope and a remote for the SupaTrak motorised mount. It's an affordable package for the beginner looking to move towards intermediate technology, though be warned, it makes no concessions for the absolute beginner. Those unfamiliar with putting a scope of this type together will be completely thrown by a manual that throws several Sky-watchers together and expects you to make sense of rudimentary instructions. But with that in mind, it would still make an excellent Christmas gift for any budding astronomer.

Verdict: ★★★

Super Precision Gyroscope & Gimbals kit

You spin me right round baby, right round...

Price: £107.64
Get it from: www.gyroscope.com
AT A GLANCE, the Super Precision Gyroscope appears to be a lump of metal cast into a spherical shape with a smaller disk on a swivel in the centre. Motionless, it's no more interesting than a paperweight but there's a clue in the name as to its higher purpose. The central disk made from solid brass with an aluminium chassis, lathed to a precise shape and set with high-grade miniature bearings. The result is centrifugal motion that almost seems self-perpetuating, due to the deliberate and time-consuming manufacturing process used to create it.

The Gyroscope comes with a small motor that spins the brass disk up to an impressive 12,000RPM, which will continue to spin for around seven minutes once the motor has been detached. The gimbals kit is sold separately and enables a dozen or so extra configurations, ideal for laboratory or classroom experiments, but it also makes an original step up from a Newton's Cradle for an executive toy.
Verdict:

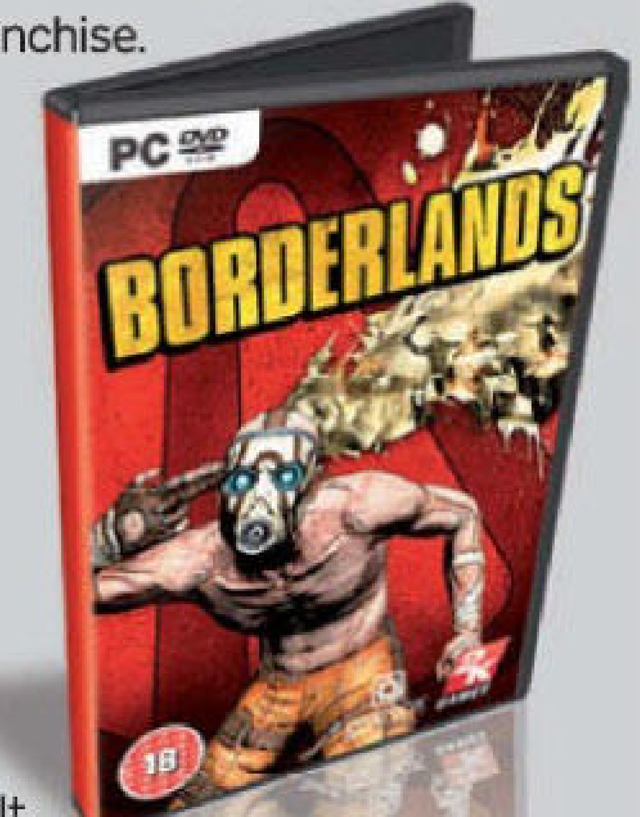
Hero's Steam Turbine

It's physics, but not as we know it

Price: £189.99
Get it from: www.gyroscope.com
THE HERO'S STEAM Turbine gets its name from the Greek mathematician, Hero of Alexandria, who is believed to have invented the predecessor to this steam turbine. Operating it is simple: syringe water into the turbine then fill the burner with methylated spirits and light the wicks for the device to spin up to speeds of around 2,500RPM. The cost of the Hero's Steam Turbine is in the precision manufacturing process rather than the materials and you'd have to have a keen interest in the sciences to foot the best part of £200 for it, but it makes an interesting addition to GCSE physics kit.
Verdict:

Ghostbusters: The Video Game

Format: 360/Wii/PS3/PC/DS/PSP
Price: £44.99
Get it from: www.argos.co.uk
The actual game part of a movie tie-in takes a back seat to huge marketing budgets and licensing fees so often that these days, we tar them all with the same brush. So spare *Ghostbusters* the same prejudice, because it's a bit of a gem really. It has all the eye-candy with none of the slapdash concept: you play a voiceless experimental weapons technician recruited by Egon to test proton pack revisions on one of the Ghostbusters' invariably dangerous contracts. With superb voice-acting and entertaining banter between the team, it's an engaging interpretation especially for fans of the franchise.
Verdict:



Borderlands

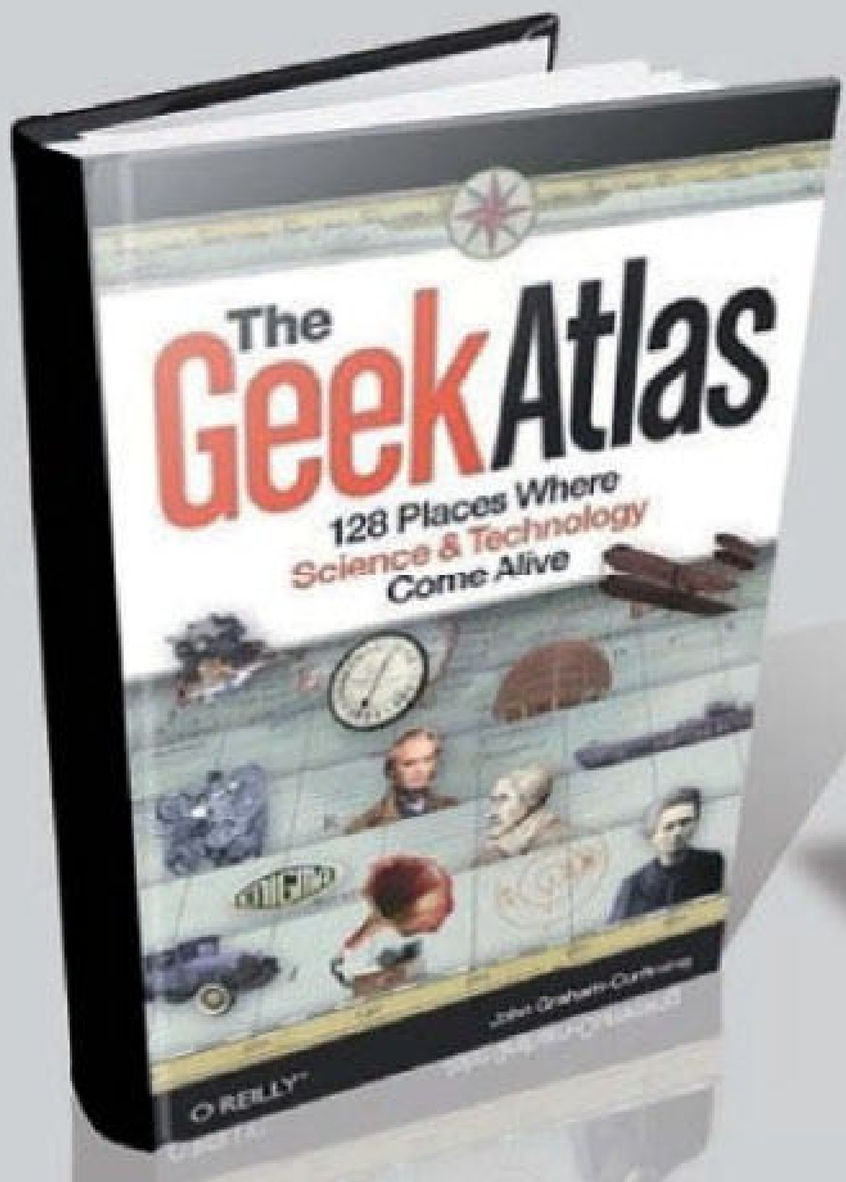
Format: PC/PS3/360 ■ Price: £34.99
Get it from: www.amazon.co.uk
Despite being the setting of a smorgasbord of games and film, there's something compelling about a post-apocalyptic wasteland setting that endures like the half-life of uranium-238. *Borderlands* capitalises on our fascination with the genre by fusing a first-person shooter with strong role-playing features and stylish cel-shaded visuals. It apes original games like *Fallout 3*, *Diablo* and cult movie *Mad Max*, but in its execution it becomes more than a sum of its parts. It excels as a multiplayer game with a party of four and with upwards of 50 hours for the main missions alone, you're getting value for money.
Verdict:

Dragon Age: Origins

Format: PS3/360/PC ■ Price: £49.99
Get it from: www.play.com
From role-play game stalwarts BioWare, creators of *Mass Effect* and *Knights Of The Old Republic*, comes a new breed of fantasy game. Actually, this low-fantasy tale of a fractured continent struggling against a supernatural terror known as the Blight, straddles PC RPG gaming of old and its successful transition onto console. *Dragon Age* couples the Canadian developer's deft touch for storyline and scripting with a seamless combination of turn-based and action-oriented combat. BioWare's knack for the illusion of complete freedom permeates dialogue throughout, lending *Dragon Age* the feel of an interactive novel between bouts of bloody combat.
Verdict:

Forza 3

Format: Xbox 360 ■ Price: £49.99
Get it from: www.game.co.uk
Forging ahead with the times, Microsoft's proud spearhead of the racing car simulation genre has included the almost ubiquitous time reversal mechanic that has come to the fore recently. Has *Forza* sold out? Absolutely not. The option to use it at any point is available, but forget about recording any legitimate lap record if you do. Plus, *Forza 3* remains stoically hardcore, with 400+ cars and realistic physics modelling. And there's the loyal *Forza* community of course: you're unlikely to find a bigger collection of car enthusiasts anywhere in the world. This is petrol-head paradise.
Verdict:

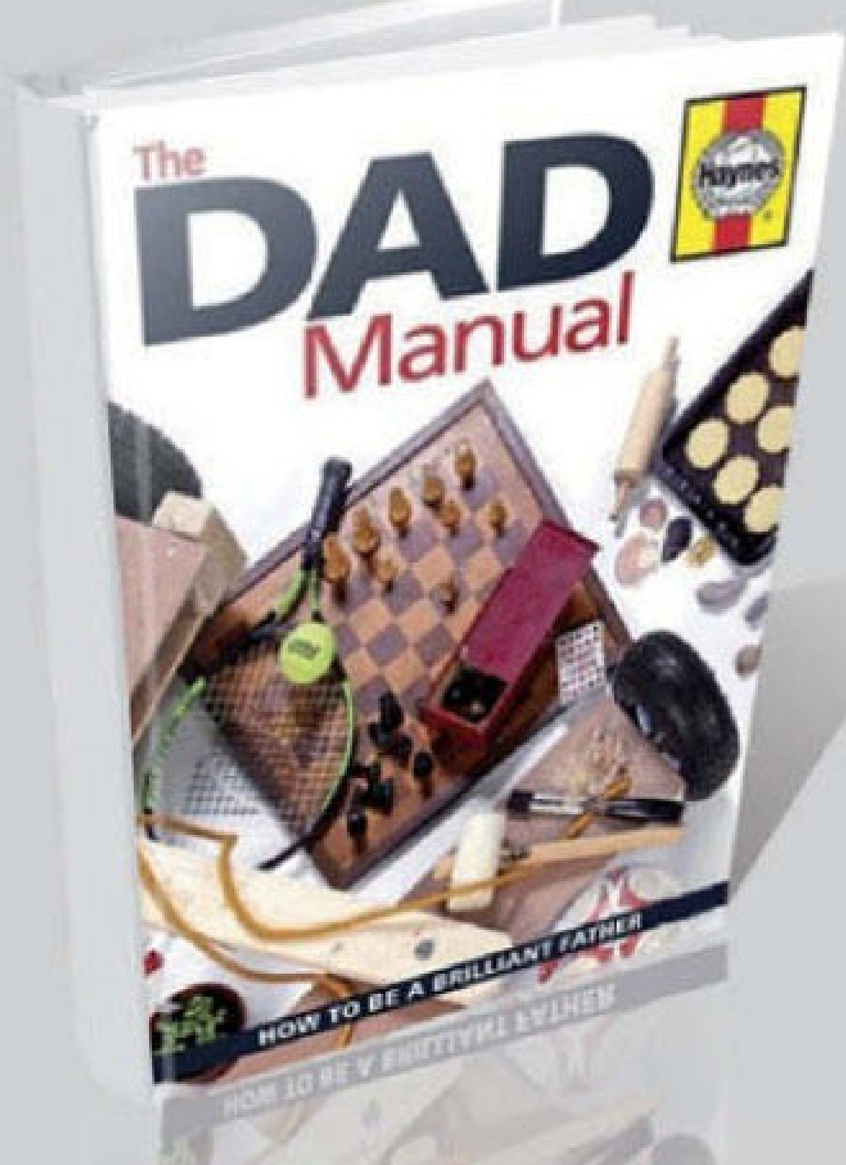


The Geek Atlas

Price: £22.99
ISBN: 978-0-596-52320-6

It's not short on facts but selecting 128 museums, research facilities and historical locations from around the world (but mostly England) gives a somewhat narrow view of human scientific achievements. This is an absorbing read but it won't be our first choice of traveller's guides when embarking on our world tour.

Verdict:



The Dad Manual

Price: £14.99
ISBN: 978 1 84425 443 9

Swallow your pride pops, and put away your jumpsuits Fathers 4 Justice: *Haynes Dad Manual* isn't a guide to good fatherhood, but with instructions on how to keep your offspring occupied with the likes of pizza planes, juggling and 'growing fun things', it will teach you the skills to make you the object of envy at your kids' primary school.

Verdict:

Seriously, what is the fastest: man or car?

Clarkson Duel

Price: £19.99
Get it from: www.amazon.co.uk

Grand piano versus Marina… who'd have thought that would happen?

Seems like a silly question, no? Yet under strict scientific controls, Jeremy Clarkson conducts an experiment pitching the motoring muscle of the Aston Martin v12 Vantage against rugby winger Tom Varndell in a 100 metre drag race. If you think the outcome is a foregone conclusion, then maybe you should steel yourself for a shock.

Clarkson Duel is a vehicle for conducting experiments ranging from those with vague rationale behind them, like whether a penny or Ford Scorpio will hit the ground first from 150 feet, to the completely crass yet entertaining exercise in pointlessness that is the demolition of a Morris Marina. Many of these are undoubtedly *Top Gear* feature rejects that failed the edit on the drawing board due to lack of scientific merit, but even if the sight of a £150,000 Ferrari California doesn't make you slightly moist, it's worth an hour of your time just to fuel your unmitigated ire for Clarkson's smug rhetoric.

Verdict:

Nikon D3000

Entry-level DSLR without the frills, but all the thrills of more sophisticated models

Price: £399 (body only)
Get it from: www.jessops.com

FOLLOWING HUGE SUCCESS with the D40, it's about time a new model filled its place. Enter the Nikon D3000. It's obvious that this camera has been built firmly with the beginner in mind, providing the learner photographer with all the manual freedom they need to get creative, while being heavily bolstered by modes and shooting functions designed to help you find your feet photographically.

The mode dial accesses Aperture and Shutter Priority, Program, Manual, Auto, six scene modes and Flash off. The final click of the dial sets you up in Guide mode, designed to tell you how to capture the pictures you don't know how to take, which has to be the D3000's crowning glory. It doesn't have the elegance of the higher-end models, but it has a fantastic 'grab and-go' feel about it which, after all, is surely what photography is all about?

Verdict:

The Curve 8520 forsakes former classy chrome for a rubber jacket

BlackBerry Curve 8520

Slimmer, lighter and cheaper: is this new BlackBerry really ahead of the curve?

Price: £221.30 SIM-free
Get it from: www.ebuyer.com

RIM HAS DECIDED to take a few chances with the new 8520. It's lighter and cheaper than the others and also the most media friendly, featuring an above average loudspeaker and a 3.5mm headphone jack. But top of the list here is the 8520's trackpad, used in place of the more traditional trackball proving both more robust and practical while still fully customisable for sensitivity. As a result the 8520 felt light to the touch, responsive and efficient for skimming menus or vertically scrolling websites.

The other obviously new feature is the rubberised coating that runs along the perimeter of the device in an effort to keep the 8520's retail and maintenance costs down – and unfortunately it's not the only one.

The camera, for instance, is a flashless two megapixel version, although picture quality was reasonable and 5x digital zoom perfectly adequate for most point-and-shoot requirements. For an entry level device aimed more at consumers, it's an interesting choice, albeit an undeniable evolution rather than revolution.

Verdict: ✿✿✿✿

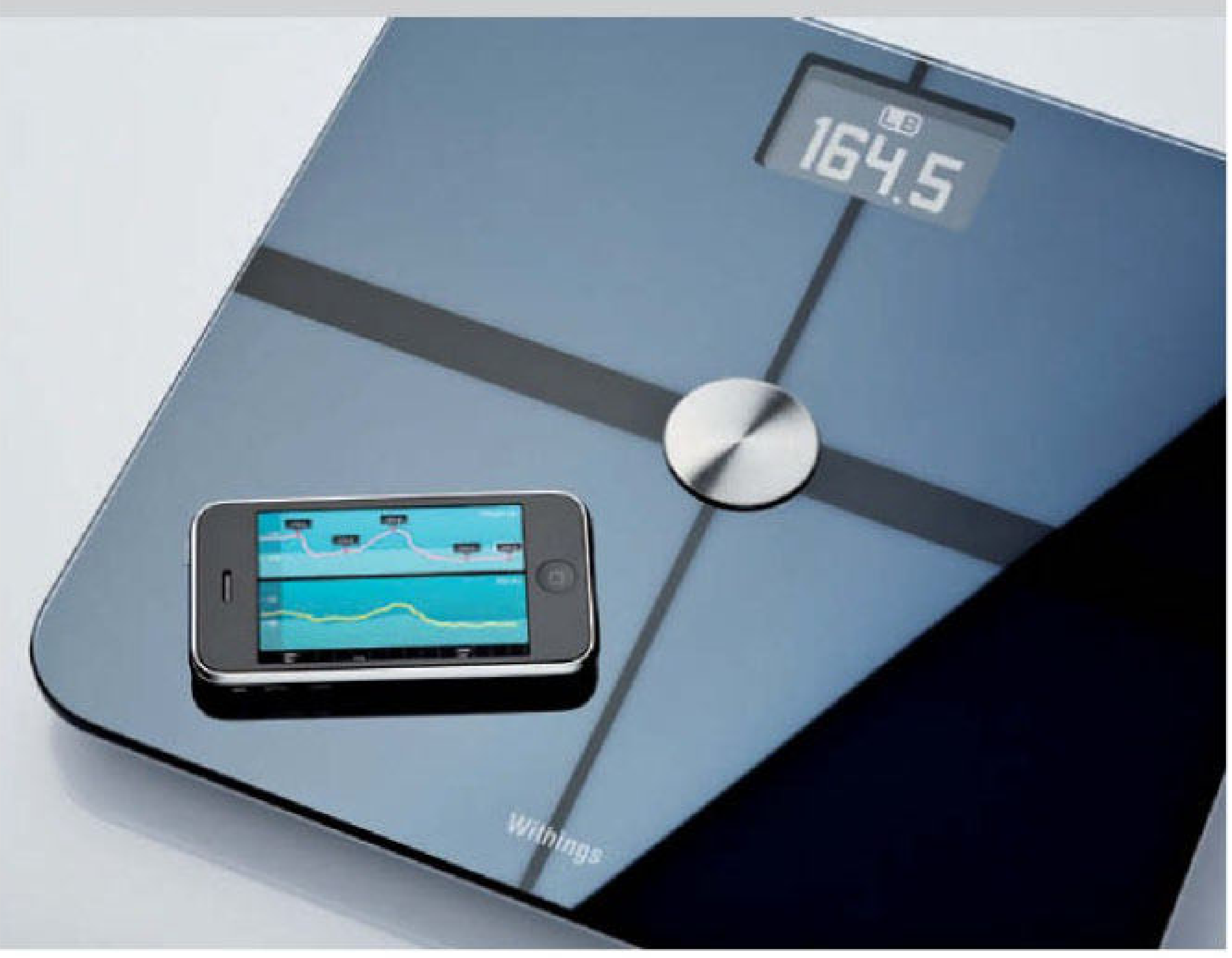
Wi-Fi Body Scale

Keep slim with the help of your Mac

Price: £129 Get it from: www.withings.com

A CONSTANT REMINDER of your rapidly expanding waistline will bring a shudder to most, but with the Connected Body Scale it needn't be that way. The device measures weight, body fat and BMI and all you have to do is log on to the provided web link, add your Wi-Fi network and a password and you'll be logged in to your own personal homepage at Withings.com, where you can view all of your measurements on a timeline graph. Wireless communication between scales, Mac and iPhone app means that you can keep tabs on your stats at all times and is an ideal way to help achieve your body goals.

Verdict: ✿✿✿✿✿



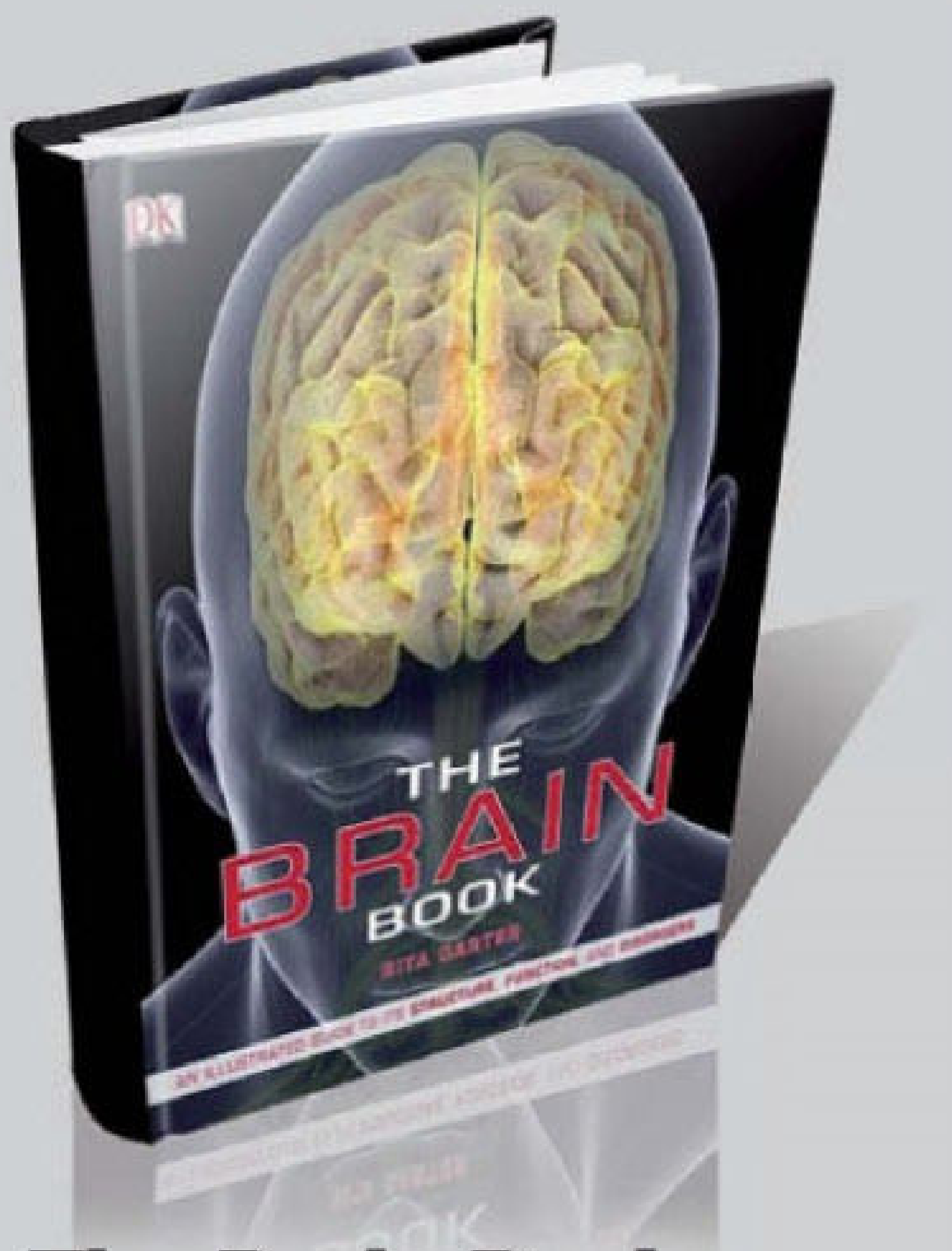
Eee Box

Small, compact and cute: does the Eee Box have the brains to match its beauty?

Price: Eee Box B202 £200, Eee Box B204 £320
Get it from: uk.asus.com

IF YOU ARE on the market for an inexpensive and small desktop machine, take a look at the ASUS Eee Box series nettops. The low-end B202 model sports the Intel Atom N270 processor, a 160GB hard disk, a wireless adaptor and a multiformat memory card slot. The high-end B204 model adds to this the ATI Radeon HD 3400 graphics card, the ability to play high-definition videos via an HDMI connector, and features a built-in Bluetooth adaptor. Both machines come with Windows XP as standard, though Linux-philes will have no problem installing a slimline version of the Red Hat OS.

Verdict: ✿✿✿✿

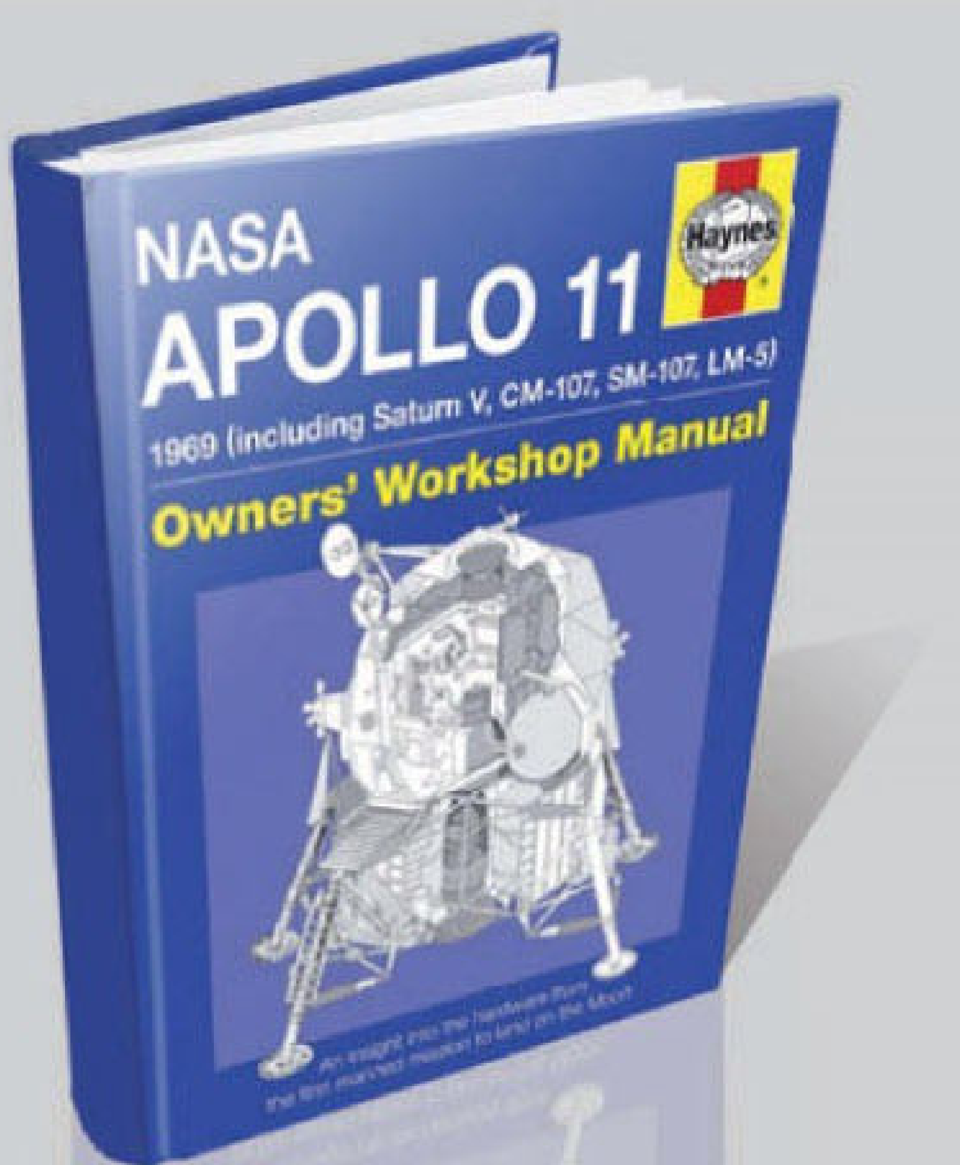


The Brain Book

Price: £25
ISBN: 978 1 4053 4129 5

An autopsy of the brain's structure, function and an insight into the history of human understanding of the brain and the frequently macabre physician practices of the past. It's peppered with CGI and illustrations that frequently lapse into bouts of experimentation, with you as the test subject. Food for the mind.

Verdict: ✿✿✿✿



Apollo 11 Owners' Workshop Manual

Price: £17.99
ISBN: 978 1 84425 683 9

No idea what to do with that re-entry capsule sitting in your back garden? This novel manual won't tell you, but it does chronicle the history of NASA mission AS-506 to the moon and all the vital statistics and diagrams of the rocket and its technology, as we've come to expect from Haynes.

Verdict: ✿✿✿

GROUP TEST

Unless you're Ray Mears, a reliable multi-tool can make all the difference. But which is best?

Multi-tools

1 Leatherman Skeletool-CX

Price: £69.95
Get it from: www.whitbyandco.co.uk

Designed with economy in mind, the Skeletool is, as the name suggests, a compact and minimal multi-tool solution. An extremely sharp locking blade comes in just under the three-inch UK legal threshold and is accessible while the tool is closed. Once opened, the Skeletool's design efficiency becomes apparent with every tool combining multiple functions, including pliers with standard and hard-wire cutters and an ingenious carabiner that doubles as an effective bottle opener. It's not the most aesthetically pleasing of multi-tools but it combines Leatherman's trademark quality with ergonomic practicality.

Verdict:

2 Wenger Ranger Alinghi Sailing Knife

Price: £89.95
Get it from: www.whitbyandco.co.uk

There's something reassuring about picking up a specialist multi-tool and not having the foggiest what some of the instruments do. The Alinghi provides the basics for a yachtsman to maintain his vessel, so in our limited knowledge of the subject we'll reserve judgement on the effectiveness of the shackle opener and marlinspike. We have to admit though, there's definite satisfaction in the size and weight of the Alinghi, plus the Swiss Army endorsement indicates the quality you can expect: particular attention must be paid to the pliers, whose simple fold-out lever mechanism is ingenious.

Verdict:

3 Buck: 730 X-Tract

Price: £49.99
Get it from: www.whitbyandco.co.uk

The Buck: 730 X-Tract boasts by far the sexiest locking blade of the multi-tool group test, which matches the Skeletool for razor sharpness. It also houses the biggest diversity of locking devices into its stubby chassis, from a simple fold-out bottle opener to an impressive spring-loaded set of pliers and a push-button screwdriver set that slides either way for the Phillips/flat head option: always handy. We're slightly dubious about the actual necessity and longevity of some of these elaborate mechanisms, but they have a definite appeal to the enthusiastic gadgeteer and, if for some reason whittling wood flicks your switch, you could look a lot less cool using an inferior blade.

Verdict:

4 Leatherman Surge Camo

Price: £129.95
Get it from: www.whitbyandco.co.uk

The popularity of the Leatherman brand doesn't come without a price and this is the most expensive multi-tool in the group. But though we'd question why a camouflaged chassis and black tools should cost so much more than the vanilla Surge (especially as we're not going to be diffusing bombs behind enemy lines in the near future), Leatherman's panache for superb craftsmanship is still the most prominent feature of the Surge Camo. For the outdoors type who wants for nothing, this is one of the most versatile tools available – even if it does look like something Mike from *Spaced* would own.

Verdict:

HOW IT WORKS INBOX

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If you must, mail your letter into us at the address below. Remember though, it's more expensive and has a far bigger carbon footprint than its digital counterpart. After the sermon, send your letter to… **How It Works, Imagine Publishing, 33 Richmond Hill, Bournemouth, Dorset BH2 6EZ**

Next month, we'll be replying to your letters and emails right here

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HOW TO MAKE
...the perfect paper plane

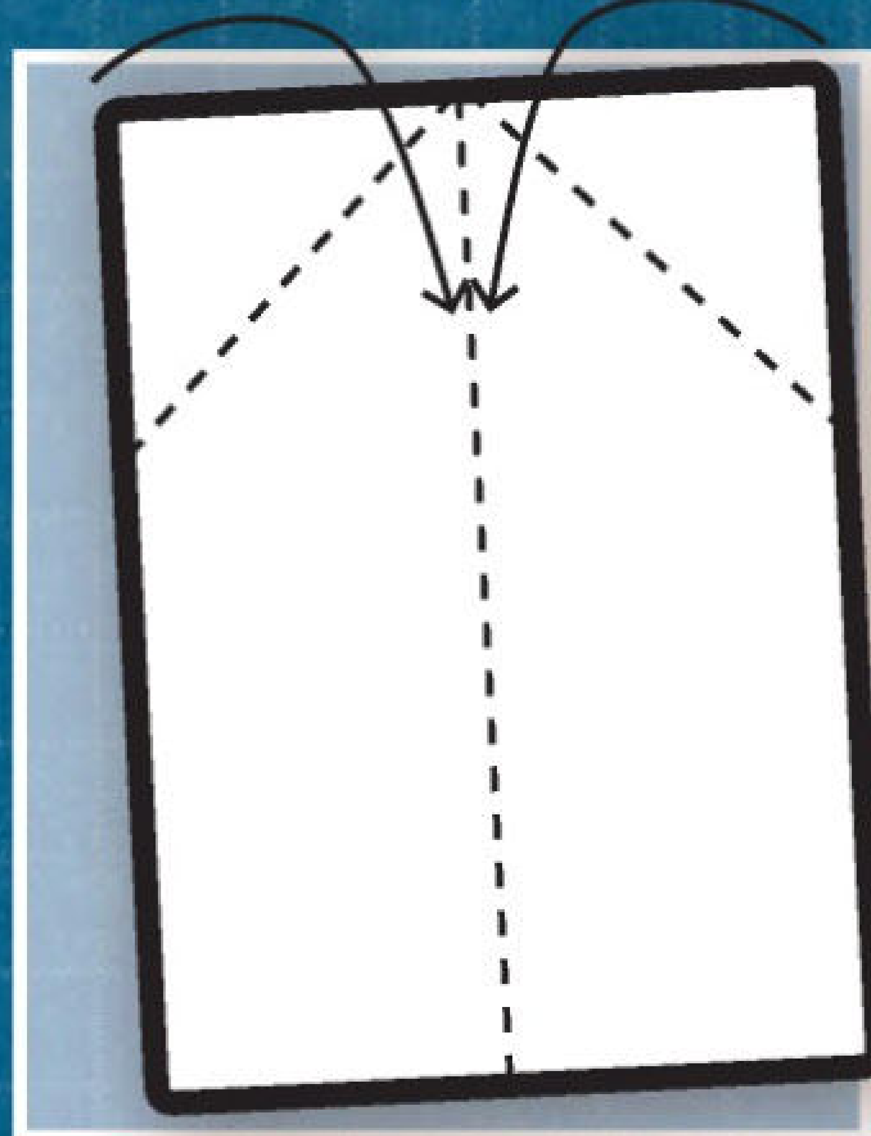
The perfect paper p

Construction materials:

1 x A4 sheet of paper
1 x ruler
2 x hands

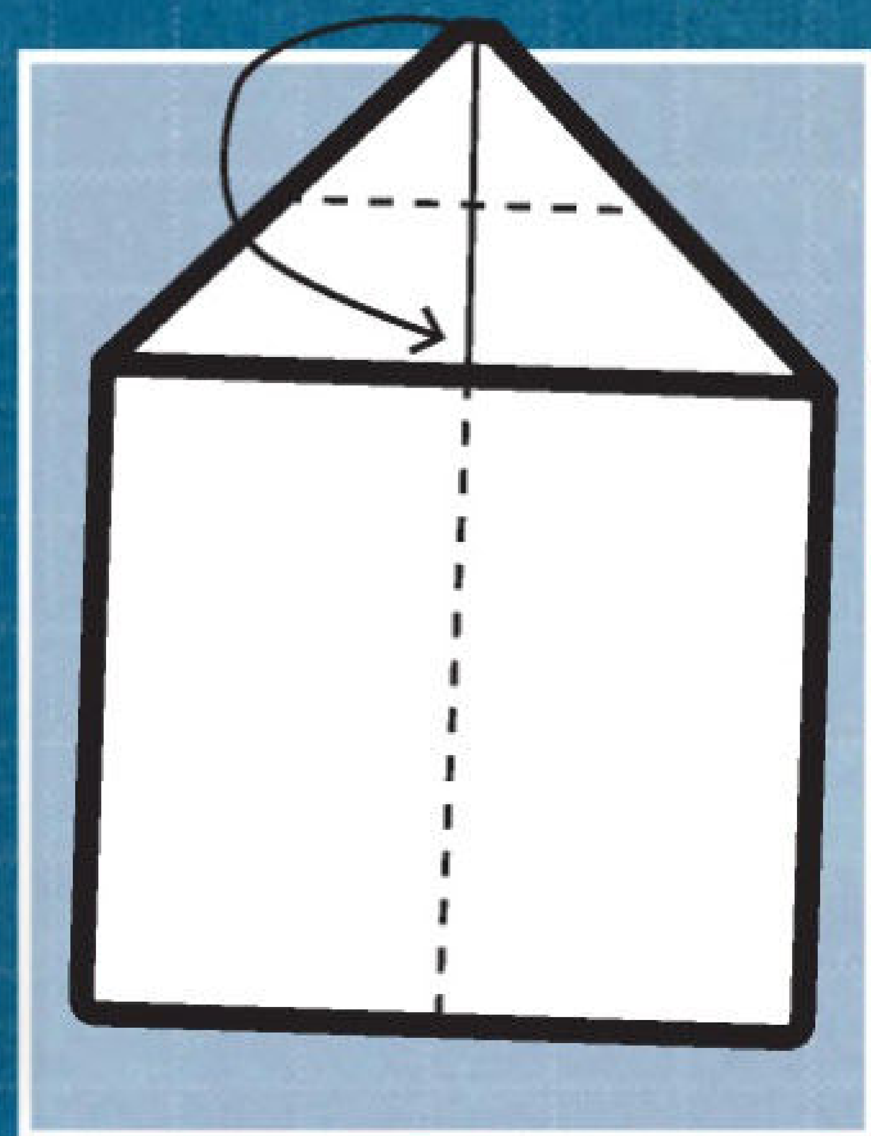
The current world record for time spent aloft by a paper plane stands at 27.6 seconds and was set by American Ken Blackburn, having held and lost the record several times previously before reclaiming it in 1998. In case you're hoping to blow his record out of the sky, Ken hit the weights to improve his throwing power and is an aeronautical engineer, so he knows a thing or two about how to keep a plane in the sky.

We've chosen this variety of paper aeroplane, commonly known as the Cobra, because of its balance between ease of construction and propensity to stay aloft. Other models require tape and scissors, but the Cobra's elegant design and delightfully graceful flight makes it a favourite on **How It Works**. The Cobra already has a fairly weighty front end, but if you want to give it a real edge, try a paper clip or two on the nose.



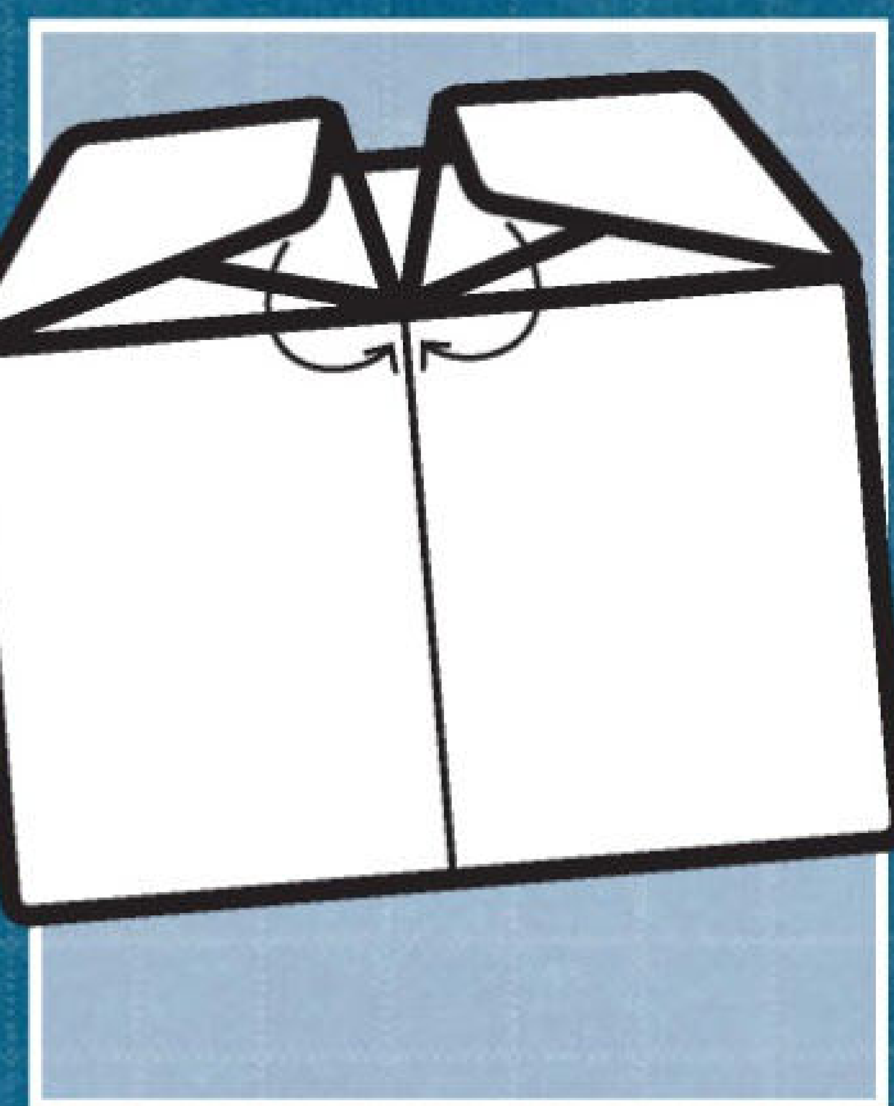
Step 01

Fold a piece of A4 paper lengthways and then open it out again. Fold the top left and right corners into the central fold as shown above.



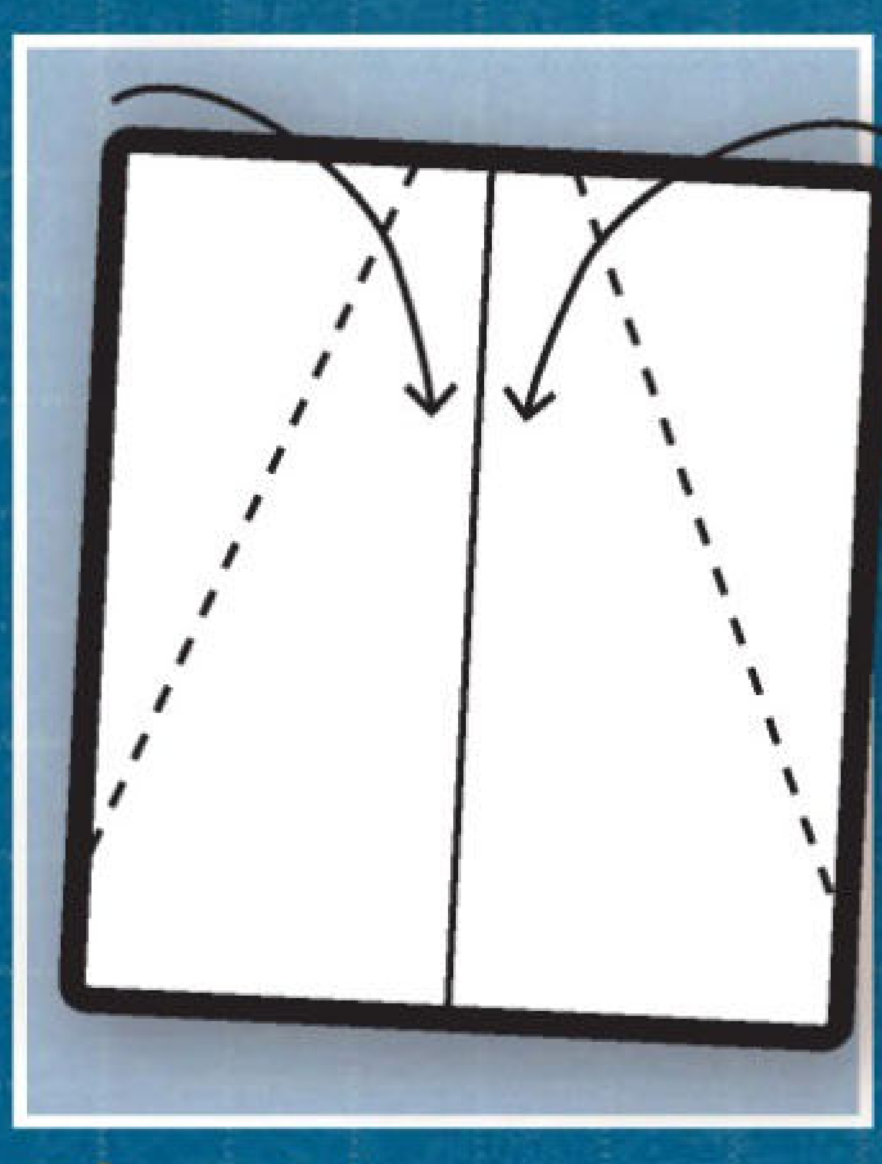
Step 02

Fold the nose along the centre line until the tip reaches the bottom of the fold. Then open up the paper right out back to its original shape.



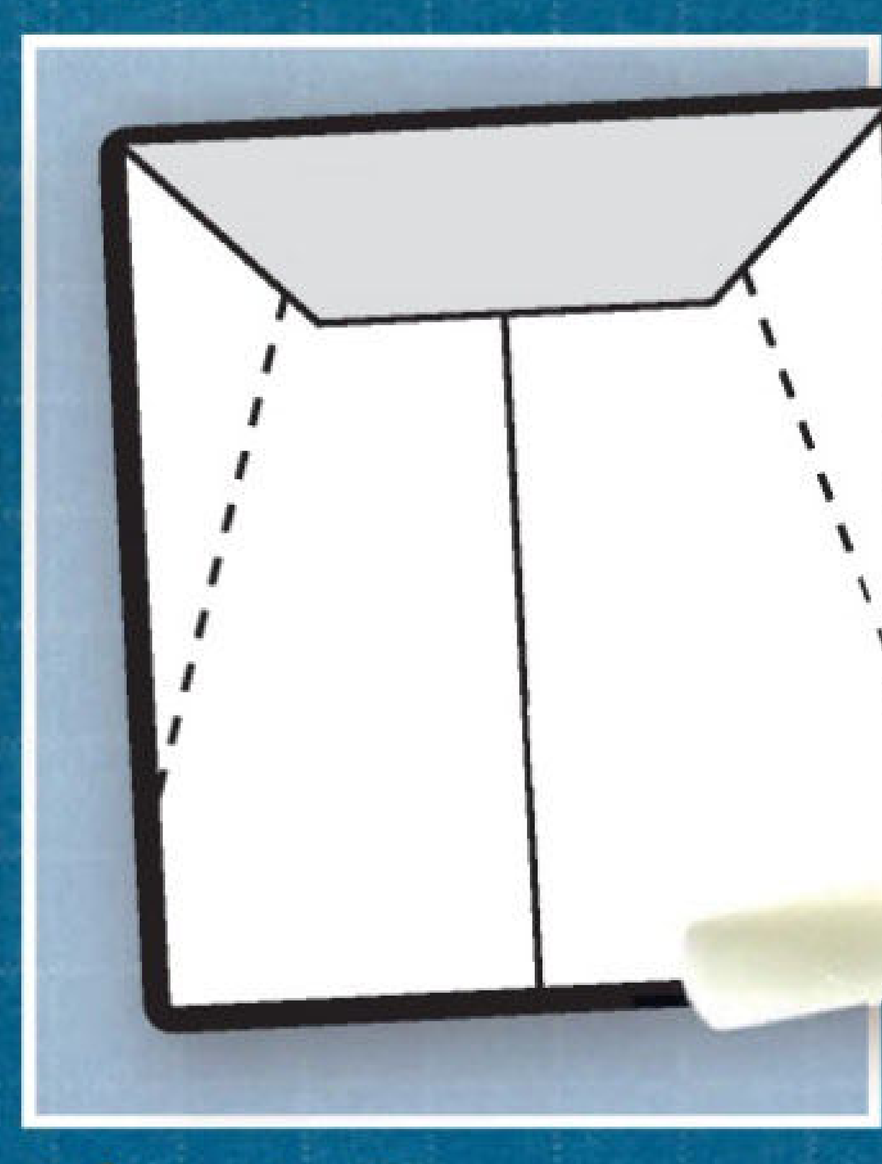
Step 03

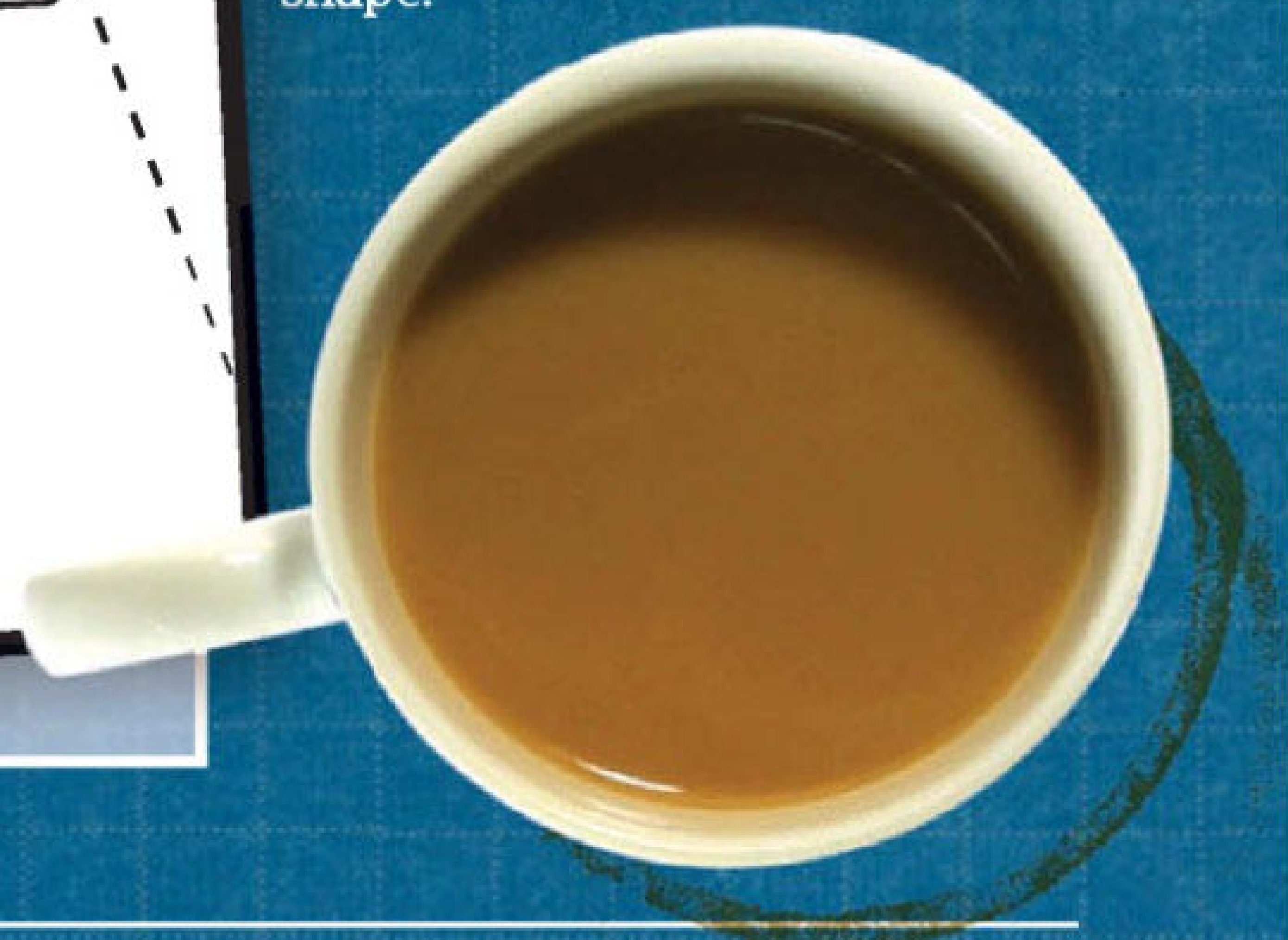
Locate the two vertical creases at the top of the paper, about two inches from the top left and right hand corners. Pull them towards each other so that they meet while the central crease forms a triangle that folds down into the middle of the paper. The top of the paper should now form a trapezium shape.



Step 06

Now repeat step five, but this time fold the corners behind the trapezium. You'll need to unfold them again and turn the paper back over.





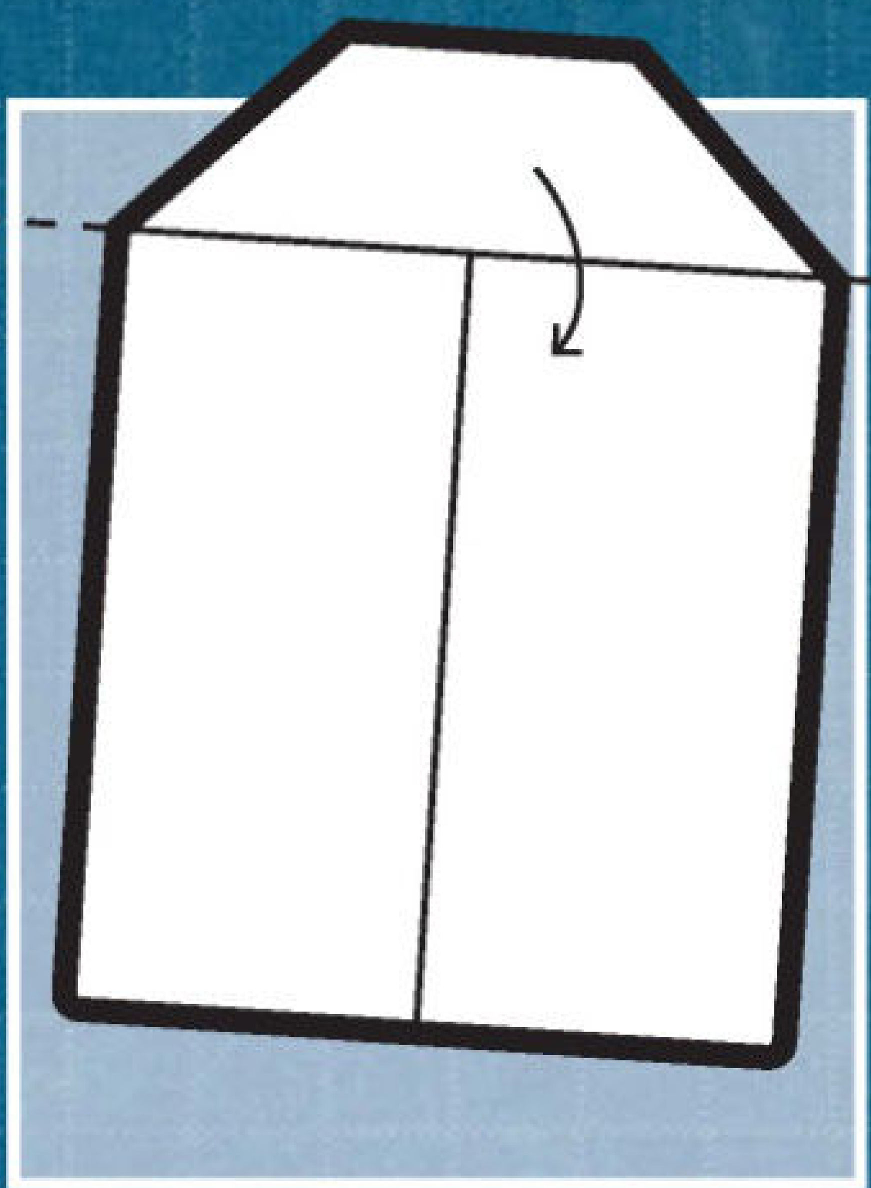
Step 07

This is the tricky part: the trapezium should currently be folded down so that the paper forms a rectangular shape, as shown above. Take the top left and right corners and tuck them into the centre so that the points meet in the middle – they should collapse neatly underneath the trapezium to form step eight.

SEE THIS PLANE BEING MADE

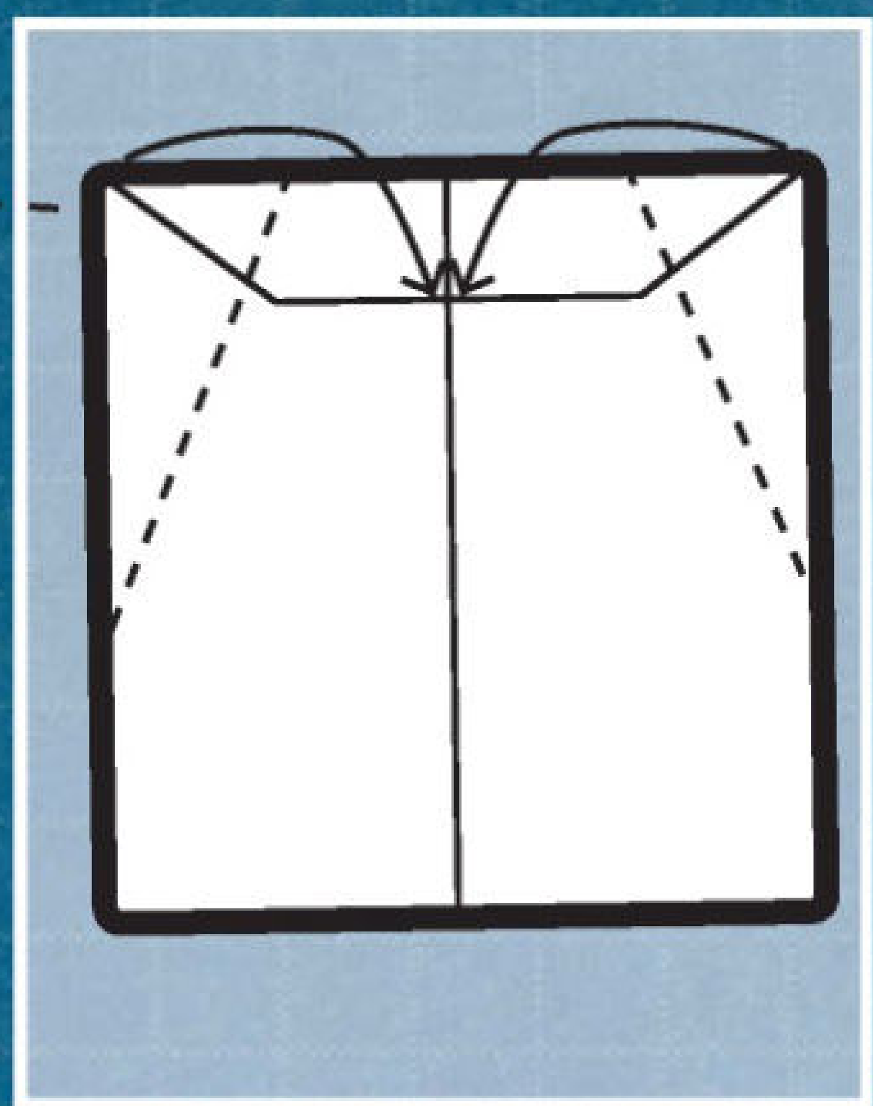
Visit www.paperairplanes.co.uk/schultz.php to watch a video of this paper plane getting constructed

plane step-by-step!



Step 04

Fold the trapezium downwards over its bottom line so that the paper forms a rectangular shape again, as can be seen in the diagram for step five.



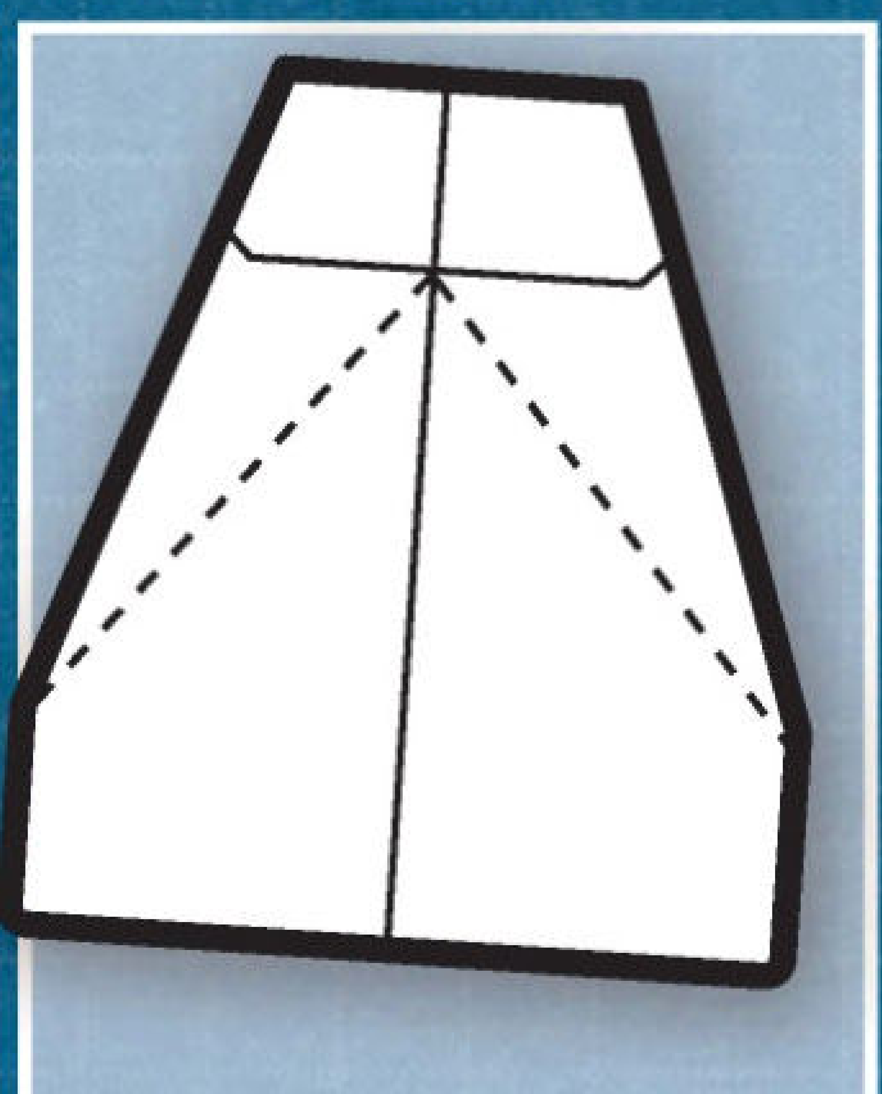
Step 05

Take the top left and right-hand corners, fold them over into the centre so that the points meet in the middle and bottom of the trapezium fold. Then unfold again.

TOP 5 PLANE MAKING TIPS

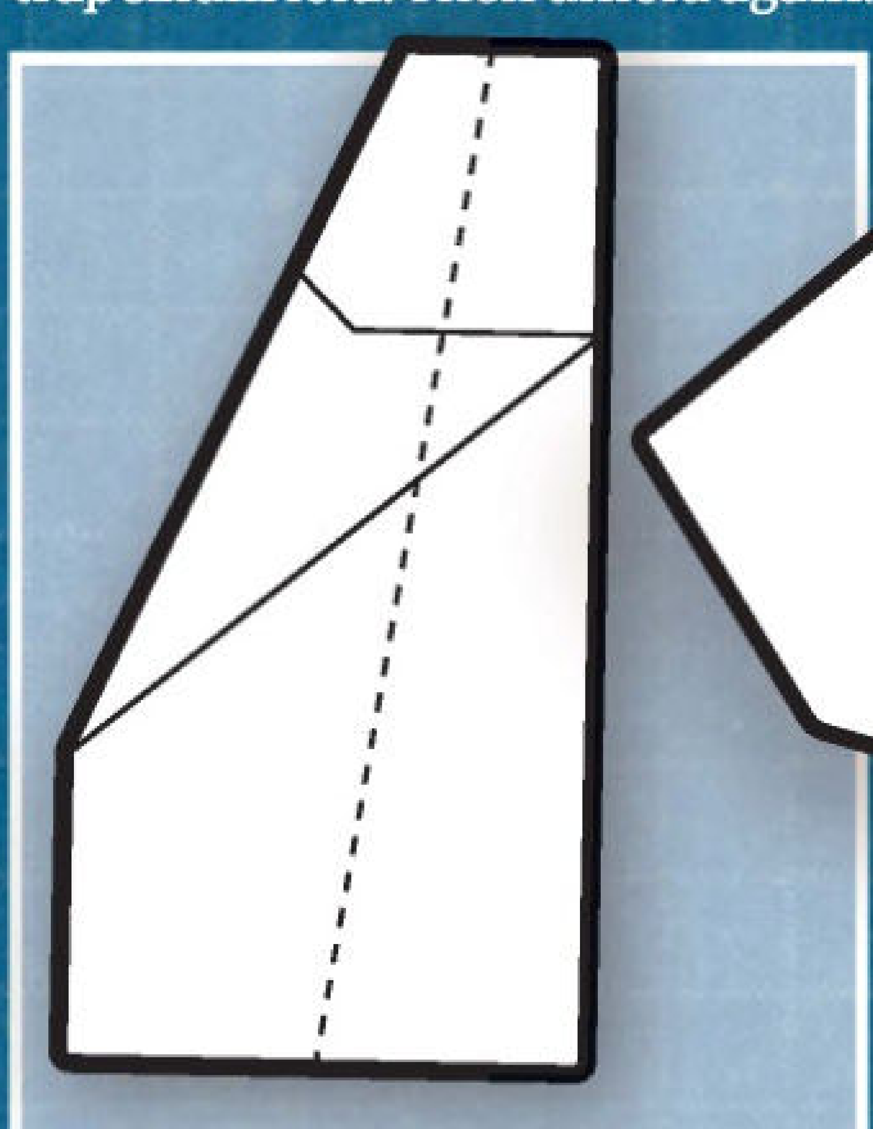
1. Ensure that the folds you make are accurate and they all line up as they should.
2. When creasing along a line, use the edge of a fingernail to make sure the fold is sharp.
3. If necessary, try a practice run first, just to get yourself familiar with the folds and how the shape progresses.
4. Use a ruler to line the edges up if you're not able to do it accurately using just your hands.
5. For extra effect, why not use different coloured paper and make a whole air force to bombard your mates at work!

TIME FOR THE TEST FLIGHT...



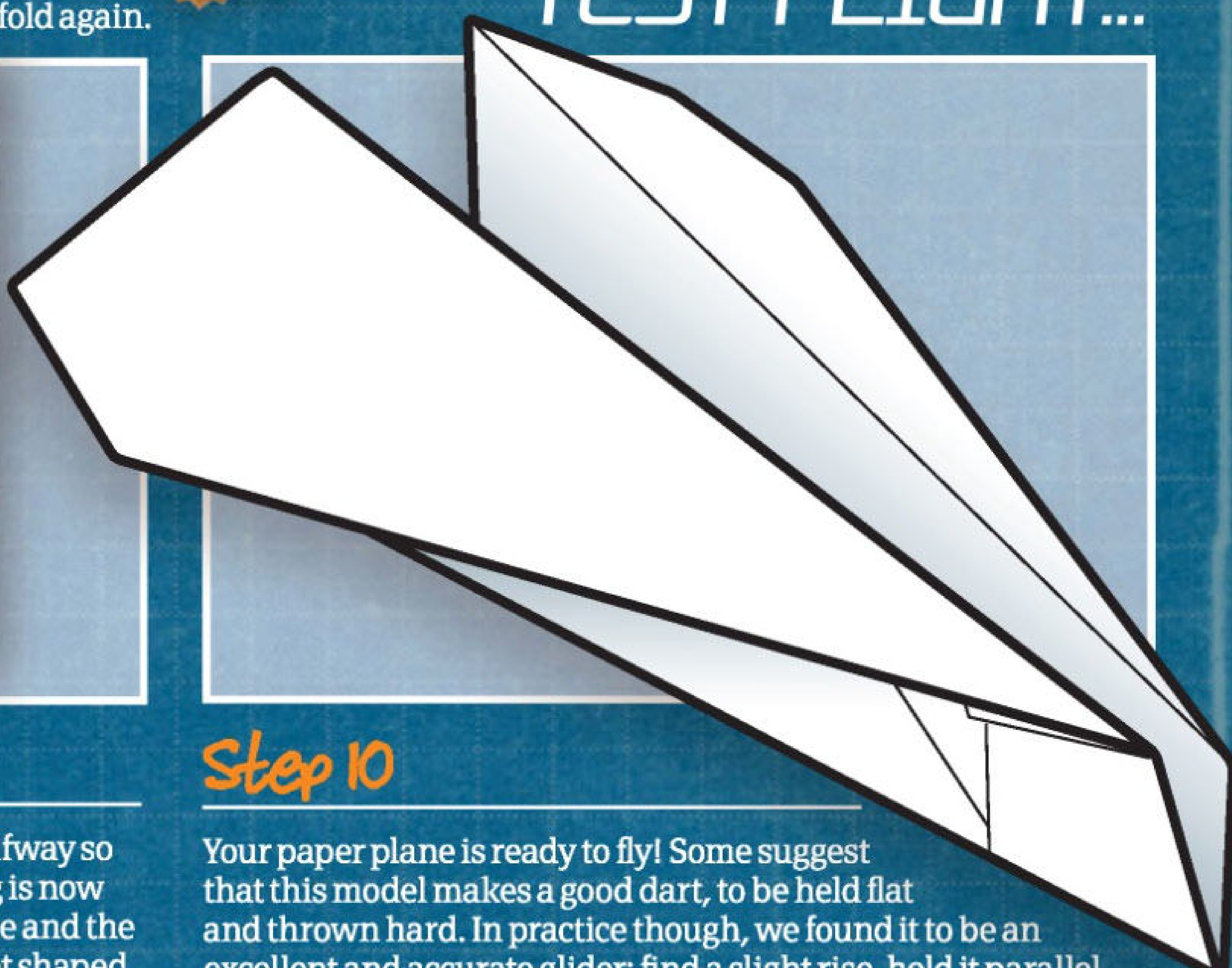
Step 08

The shape of the plane should be obvious by now. Turn the paper over then fold it in half along the central crease, making sure that the flaps remain on the outside.



Step 09

Fold the wings down halfway so that the edge of the wing is now parallel with the fuselage and the nose remains flat, but not shaped to a point.



Step 10

Your paper plane is ready to fly! Some suggest that this model makes a good dart, to be held flat and thrown hard. In practice though, we found it to be an excellent and accurate glider: find a slight rise, hold it parallel to the ground and use your arm more than your wrist to gently push it airborne.

HOW IT WORKS

NEXT MONTH…

What on earth is this?

Find the answer in the next issue of How It Works…

ON SALE 26 NOV 2009

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